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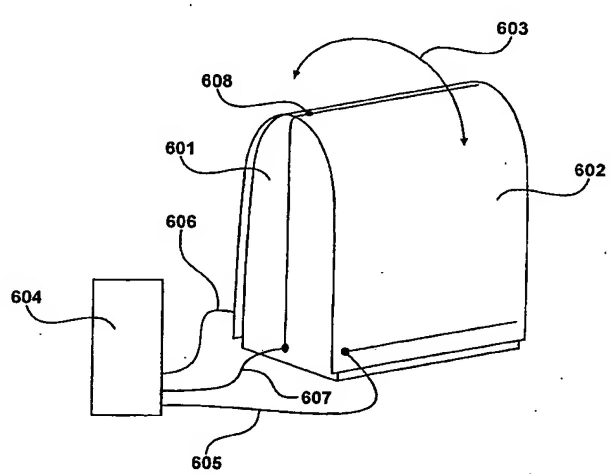
(54) Title: MANUALLY DEFORMABLE INPUT DEVICE



(57) Abstract: A manually deformable input device responsive to manually applied pressure. The input device comprises a deformable electroconductive material (602) configured to exhibit changes in conductance (resistance) in response to being stretched or compressed, from which an extent of manually applied pressure can be determined. An electrical interface device (604) is configured to supply electrical current through the electroconductive material (602) via a first terminal (605) and a second terminal (606), and the input device further comprises a third terminal (607) connected at a position intermediate the first and second terminals. The electrical interface device (604) is configured to receive a voltage from the third terminal (607), which is representative of a proportion of voltage drop across the electroconductive material (602). The input device operates as a potential divider sensitive to manual operation irrespective of the absolute conductance (resistance) of the electroconductive material (602).

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Manually Deformable Input Device

Background of the Invention

1. Field of the Invention

The present invention relates to a manually deformable input device responsive to manually applied pressure. The input device may have control applications, such as controlling a motor or providing an input command to a game. Alternatively, the input device may be used to monitor conditions and, for example, to provide an output signal so as to raise an alarm condition.

2. Description of the Related Art

A deformation sensitive electroconductive device is disclosed in United States Patent 4,715,235 in which a knitted or woven fabric has electroconductivity that changes in response to the fabric experiencing a deformation. In a detailed embodiment, a fabric is applied over a finger of an operative and finger movement is detected by detecting changes in the resistivity of the fabric. The fabric is modelled as a variable resistance and the resistivity of the fabric is measured in order to determine that a movement has been made.

A problem with fabrications of this type is that the resistive fabric element will undergo resistance changes in response to other changing conditions, such as temperature and ageing etc. such that its effective sensitivity significantly reduces the available applications for the device. Consequently, it is unlikely that the system described in the aforesaid US Patent could reach a satisfactory commercial realisation; other technologies being preferable for their inherent stability features.

It has been realised that fabric solutions do have advantageous application in some situations, particularly if costs are to be reduced or if the control mechanism is to be incorporated within soft structures or products. Thus, for example, it is possible that devices of this type could be used to make modifications to the position and orientation of seats in vehicles in preference to additional mechanical switches etc. Thus, in such an application, in preference to switches being operated manually, portions of a car seat itself could be manipulated so as to effect movement and reconfiguration. Such an approach may reduce production costs while providing a more elegant and attractive solution.

Brief Summary of the Invention

According to an aspect of the present invention, there is provided a manually deformable input device responsive to manually applied pressure, comprising a deformable resilient element configured to deform in response to said manually applied pressure, operatively coupled with an electroconductive material applied configured to exhibit changes in conductance (resistance) in response to being stretched; and an electrical interface device configured to supply electrical current through said electroconductive material via a first terminal and a second terminal, wherein, a third terminal is connected at an intermediate position; and said interface device is configured to receive a voltage from said third terminal.

According to a second aspect of the present invention, there is provided a deformable input device having an additional fourth terminal. The fourth terminal enables deformation of the input device to be detected in two dimensions.

According to a third aspect of the present invention, electroconductive

material is operatively coupled to a three-dimensional deformable resilient element.

According to a fourth aspect of the present invention, there is provided a deformable input device in which the deformable resilient element and the electroconductive material are provided by an elastomeric electroconductive textile. By utilising a frame, a substantially two-dimensional manipulation area can be formed.

Brief Description of the Several Views of the Drawings

Figure 1 shows an electroconductive yarn;

Figure 2 illustrates a weft knit;

Figure 3 shows the weft knit of *Figure 2* following stretching;

Figure 4 illustrates a relationship between resistance change and elongation;

Figure 5 details a linear region identified in *Figure 4*;

Figure 6 shows a manually deformable input device embodying the present invention;

Figure 7 illustrates the relationship between stretch and resistance of the device shown in *Figure 6*;

Figure 8 illustrates an electrical model of the device shown in *Figure 6*;

Figure 9 further illustrates the relationship between stretch and the resistance change for the device shown in *Figure 6*;

Figure 10 shows an alternative embodiment;

Figure 11 shows a top view of the embodiment shown in *Figure 10*;

Figure 12 further illustrates the alternative embodiment of *Figure 10*;

Figure 13 details the interface circuit for the device shown in *Figure 10*;

Figure 14 illustrates the device of *Figures 10* and *11* connected to the interface circuit shown in *Figure 13*;

Figure 15 shows an alternative embodiment of input device;

Figure 16 shows an alternative embodiment of input device;

Figure 17 further illustrates the alternative embodiment of *Figure 16*;

Figure 18 details procedures performed by the interface circuit for the embodiment shown in *Figure 16*;

Figure 19 shows an application of the device of *Figure 16*;

Figure 20 illustrates the configuration shown in *Figure 19* in use;

Figure 21 illustrates an alternative application for a deformable input device;

Figure 22 illustrates an alternative form of input device;

Figure 23 illustrates a further alternative embodiment of input device;

Figure 24 illustrates an alternative embodiment of input device;

Figure 25 illustrates the input device of *Figure 24* following manipulation;

Figure 26 illustrates an alternative embodiment of input device.

Written Description of the Best Mode for Carrying Out the Invention

Figure 1

An electroconductive yarn is shown in *Figure 1*, constructed from an electrically conductive yarn **101** and an electrically insulating yarn **102**. In this preferred embodiment, the electrically conductive yarn **101** is wrapped around the insulating yarn **102**. The conductive yarn may be fabricated from a conventional yarn having a carbonised or metallised outer surface and the insulating yarn **102** may be fabricated from polyester. In this example, the

conductive yarn **101** has a size of twenty-four decitex whereas the insulating yarn **102** has a size of twelve decitex. According to a preferred embodiment, six filaments of twenty four decitex carbon coated nylon are twisted together with twelve filaments of twelve decitex polyester yarn. By using conducting yarn having a diameter greater than the insulating yarn, the twisted composite yarn can be formed with prominent conductive elements at the surface.

It can be appreciated that an electrical current may flow down the conductive yarn **101**. In addition, when yarns are in close proximity, or loops of the same yarn are in close proximity, a current may also flow between the yarns or loops. Furthermore, when yarns are in close proximity planar resistance tends to reduce, whereas forcing the yarns away from each other, by a stretching operation for example, results in the overall planar resistance increasing.

Figure 2

A construction that emphasises the effect of resistance changes with respect to stretch is illustrated in *Figure 2*. This consists of a weft knit where individual yarns **201** run from a left position **202** to a right position **203**. In a preferred application, a voltage is applied across the plane so as to promote current flow in the direction of arrow **204**; that is to say substantially perpendicular to the direction of the individual conducting yarns, i.e. in the warp direction.

An electroconductive fabric that exhibits a change of resistance in response to stretching can be created using other constructions including warp knit, weave and crochet constructions; and may incorporate composite yarn, such as the conductive yarn shown in *Figure 1*, yarn comprising staple

or monofilament fibres, or elastic fibres, for example in a yarn having conductive or insulating fibres wrapped around an elastic centre. In addition, conductive yarn and insulating yarn may be twisted together prior to the construction process or, for example, conductive yarn can be incorporated during the construction process. Thus, electroconductive materials with different characteristics can be created using different constructions, materials and, for example, stitch sizes.

Figure 3

The weft knit construction illustrated in *Figure 2* is also shown in *Figure 3*, after the material has been stretched in the direction illustrated by arrow **301**. This has resulted in an increase in the separation between the individual yarns such that fewer paths now exist for current flow and hence the planar resistance has increased. Thus, it is possible for this property to be used in order to determine the extent of stretch which in turn may be related back to an extent of manually applied pressure.

According to an alternative warp knit construction (not shown) conductive in the warp direction, the planar resistance decreases in response to stretching in the warp direction. Thus, although this type of construction responds differently to the described weft knit construction shown in *Figures 2* and *3*, it possesses the same property of exhibiting a change in resistance in response to being stretched, from which an extent of manually applied pressure can be determined.

Figure 4

A relationship between resistance change and sheet elongation is illustrated in *Figure 4*. It can be seen from *Figure 4* that for the weft knit fabric

shown in *Figures 2* and *3*, a percentage increase of elongation of approximately forty percent results in a resistance change of approximately five hundred percent. Furthermore, for elongations between zero and forty percent the increase in resistance is relatively linear. For elongation beyond forty percent the relationship tends to become non-linear. Thus, the linear portion provides a preferred operational region for control purposes.

Figure 5

The linear region of operation identified in *Figure 4* is detailed in *Figure 5*. Thus, by measuring resistance change it is possible to identify percentage elongations over a range of zero to forty percent.

Figure 6

A manually deformable input device responsive to manually applied pressure is detailed in *Figure 6*. The device includes a deformable resilient element **601**. Resilient element **601** may be fabricated from closed cell foam, elastomeric silicone rubber or similar elastomeric materials. The deformable element **601** is covered with an electroconductive material **602** such as the weft knit material illustrated in *Figure 2*. Thus, electroconductive material **602** is configured to exhibit changes in conductance (resistance) in response to being stretched.

Stretching occurs locally by moving the resilient element **601** in the directions illustrated by arrow **603**, which results in one side of the device experiencing elongation while the opposite side of the device experiences compression. Alternatively, stretching occurs when pressure is applied to a region of the deformable element **601**, for example a discrete region on one side of the deformable element **601** only, which results in deformation of one

side of the deformable element **601** relative to the other. In addition, the electroconductive material **602** has a thickness that is responsive to manually applied pressure. A relationship exists between the thickness and the conductivity of electoconductive material **602**, such that a change in the thickness of the material **602** under manually applied pressure results in a corresponding change in conductivity. Thus, electroconductive material **602** is responsive to different types of manipulation of the resilient element **601**. It is to be appreciated that the electroconductive material is operatively coupled to the deformable resilient element. The electroconductive material is therefore responsive to deformation experienced by the resilient element.

An electrical interface device **604** is configured to supply electrical current via a first terminal **605** and a second terminal **606**. Thus, with a current flowing from one terminal to the other, the resistance of the electroconductive material **602** results in a voltage drop occurring between the two terminals.

A third terminal **607** is connected at an intermediate position **608**, along the conductive fabric, between the first and second terminals **605, 606**. The interface device **604** receives a voltage from the third terminal **607**, representing a proportion of the voltage drop occurring through the electroconductive material. Thus, in this way, the third terminal **607** provides a tap into the voltage gradient, in the present example at the central intermediate position **608**. The total configuration therefore operates as a potential divider sensitive to manual operation irrespective of the absolute resistance of the overall electroconductive fabric. Thus, in this way, it is possible to obtain significantly higher levels of sensitivity and predictability such that the mechanism may be used in many control situations where

known technologies, merely directed towards measuring resistance per se, would not be applicable.

Figure 7

The relationship between stretch and resistance, for the device shown in *Figure 6* is illustrated in *Figure 7*. When force is applied in the direction of arrow **701**, the device is elastically forced from the position shown at **702** to, for example, a position shown at **703**. This results in a left wall **704** being elongated while a right wall **705** is compressed.

An electromotive force of three volts is applied across terminals **605** and **606**. Before a manual force is applied, resistances **706** and **707** will tend to be substantially equal such that the voltage appearing at the third terminal **607** will tend to be 1.5 volts; i.e. the voltage is being divided substantially equally. As force is applied, resulting in the device being bent towards position **703**, the compression applied to resistance **707** will tend to reduce resistance whereas the extension applied to resistance **706** will tend to increase its resistance. With the resistance at **706** being increased, there will tend to be a greater voltage drop across this resistance with a relatively lower voltage drop occurring across resistance **707**. Thus, for example, when stretched to position **703**, two volts may be measured at the third terminal **607**. Thus, detecting a voltage change from 1.5 volts to 2 volts over the linear period of operation, as illustrated in *Figure 5*, allows a relatively accurate measurement to be determined as to the extent of bending that has occurred between positions **702** and **703**. In this way, the input device is responsive to tensile forces.

Due to the operative coupling between the resilient element and the

electroconductive material, following release of applied pressure resulting in deformation of the input device, the resilient element and the electroconductive material are together returned into the unbent condition.

Figure 8

An electrical model of the device shown in *Figure 6* is illustrated in *Figure 8*. This consists of a first variable resistor **801** in series with a second variable resistor **802**. A central tap **803** completes the potential divider. Thus, as previously described, a voltage is applied across terminals **605** and **606** and the divided voltage is measured at the third terminal **607** via tap **803**.

The nature of the device is such that the variable resistors **801** and **802** may be considered as being ganged. However, an inverse relationship typically exists between the variable resistors such that an operation to increase the resistance of one will normally result in a decrease of the resistance of the other. However, it should be appreciated that in the actual device relative rates of change will differ. Consequently, bending of the device will tend to increase the resistance of the stretched resistor to a greater extent than a decrease in the resistance of the compressed resistor. Thus, the configuration provides a potential divider that appears similar to a potentiometer but has somewhat different operational characteristics. For example, a change in the magnitude of one resistance may be exhibited while the magnitude of the other resistance may be substantially maintained.

Figure 9

A further representation of the relationship between resistance changes and bending is illustrated in *Figure 9*. In its unbent condition, each side of the conductive fabric displays a resistance of five thousand ohm (5k)

and the applied voltage of three volts is divided equally. Consequently, the voltage measured at the third terminal is substantially 1.5 volts.

As the device is bent to the right, as shown at **901**, the stretched resistance **902** will tend to increase and the compressed resistance **903** will tend to decrease. Thus, a greater voltage drop will occur across resistance **902** resulting in the tapped voltage reducing from 1.5 volts to one volt.

Similarly, if the device is bent to the left, as illustrated at **904**, resistance **902** will tend to decrease while resistance **903** will tend to increase. Consequently, in this example, the tapped voltage has increased from 1.5 volts to two volts.

However, the present invention provides a manually deformable input device that is responsive to other forms of manipulation. Different patterns of voltage change can be related to different types of manipulation and device structure. For example, a manually deformable input device having the electrical configuration of the device shown in *Figure 6* can be utilised within a car seat cushion, in which the cushion is supported on the underside by a substantially rigid panel, and the topside is exposed to allow manual manipulation of the cushion. With this arrangement, the cushion deforms under the weight of a person sitting upon it, however, deformation of the underside of the cushion is negligible relative to the deformation of the topside of the cushion. Consequently, a significantly greater change in conductivity of the topside of the cushion, compared to the underside, occurs. Thus, a change in conductivity of the topside relative to the underside is exhibited, from which deformation can be detected. In this example, the detected deformation is primarily compression or indentation in nature, resulting from, for example, a person pressing the cushion with a finger.

Such a cushion may comprise a single manually deformable input

device, or may comprise a plurality of such devices, such that deformation in different areas of the cushion can be detected. Such a cushion can be utilised as a control or control panel, or as a monitoring aid to monitor, for example, the length of time a person is sitting, the frequency of use of a seat, or the sitting position of one or more persons.

Figure 10

An alternative embodiment is illustrated in *Figure 10*. A deformable resilient element **1001** is responsive to deformation in two dimensions, illustrated by a first arrow **1002** and a second arrow **1003**. The device has a substantially square cross-section defining four surfaces; a first **1004** and a second **1005** surface are shown in the Figure, with a third **1006** and a fourth surface **1007** being on the reverse side. Each surface **1004** to **1007** has an electroconductive fabric portion applied thereto; shown in *Figure 10* is fabric **1008** applied to surface **1004** and fabric **1009** applied to surface **1005**. An electrical terminal is connected to the bottom of each conductive fabric **1004** to **1008**; shown in *Figure 10* is terminal **1010** applied to conductive fabric **1008** and terminal **1011** applied to conductive fabric **1009**. The conductive fabrics are electrically connected towards the top of the device, in this example by means of a conductive band **1012**. Other connection means include adhering or stitching the conductive portions together directly or via a conductive ring.

According to the present embodiment, to simplify construction of the deformable input device, a separate third terminal voltage dividing tap is not provided. In operation, current is applied through opposing conductive portions while a third portion, on one of the other two surfaces, provides the voltage dividing tap. By scanning pairs of opposed conducting surfaces in

alternating sequence, deformation in the two illustrated dimensions can be detected. Thus, this mode of operation in effect utilises two potential dividers. Using similar conductive material on each surface of a pair offsets effects resulting from changes in temperature, humidity etc.

According to an alternative embodiment, a separate voltage dividing tap connected to conductive band **1012** is provided. According to a further alternative embodiment, two manually deformable input devices according to the embodiment described with reference to *Figures 6* to *8* are placed upon deformable resilient element **1001**, such that deformation can be detected in the two illustrated directions, and two separate voltage dividing taps are provided.

Figure 11

A top view of the device illustrated in *Figure 10* is shown in *Figure 11*. In addition to terminals **1010** and **1011** (shown in *Figure 10*) terminals **1101** and **1102** are also shown in *Figure 11*. Terminal **1010** is connected to conductive fabric **1008** and terminal **1011** is connected to conductive fabric **1009**. Similarly, terminal **1101** is connected to conductive fabric **1003** and terminal **1102** is connected to conductive fabric **1004**; applied to vertical surface **1006** and **1007** respectively.

Figure 12

An electrical representation of the configuration shown in *Figures 10* and *11* is illustrated in *Figure 12*. This consists of four variable resistors **1201**, **1202**, **1203** and **1204** each connected to a central point **1205**.

Figure 13

An interface circuit **1301** for the device shown in *Figures 10* and *11* is shown in *Figure 13*. The interface circuit includes a PIC processor **1302** configured to supply output signals to terminals and to receive input signals from terminals. The device includes four interface terminals **1303**, **1304**, **1305** and **1306**. Terminal **1303** connects to **1010**, terminal **1304** connects to **1011**, terminal **1305** connects to terminal **1102** and terminal **1303** connects to terminal **1101**.

Under program control, output voltages are generated by the processor **1302**, from pins ten, eleven, twelve and thirteen. Similarly, input voltages are received at pins seventeen and eighteen via buffer amplifier stages **1307** and **1308**. In operation, voltage is applied across terminals **1303** and **1305** resulting in a voltage being applied across terminals **1010** and **1102**. A voltage is received at terminal **1305** and supplied to the PIC processor via amplifier **1308**. This is then followed, in a multiplexed fashion, by a voltage being applied across terminals **1304** and **1305** such that an input voltage may be received on terminal **1303** and supplied to the PIC processor via buffer amplifier **1307**. Response details are stored within the PIC processor **1302** thereby allowing it to produce an output signal on an output terminal **1309** indicative of the degree of manipulation, for example, bending.

Figure 14

The input device of *Figures 10* and *11* is shown connected to the interface circuit of *Figure 13* in *Figure 14*. The interface circuit **1301** applies a voltage across surfaces **1008** and **1104** whereafter a tapped input voltage is

received from surface **1103** and applied to input terminal **1305**. After an input measurement has stabilised, the output voltage is removed to be replaced by an alternative output voltage across surfaces **1009** and **1103**. Subsequently, an input voltage is received from surface **1008** and applied to input terminal **1303**.

The PIC processor performs appropriate calculations to determine the nature of the displacement of the device to provide an output signal at terminal **1309**. In this example, the output signal is supplied to a power amplifier **1401** which in turn drives an actuator **1402**. The actuator could, for example, be a motorised car seat adjustment motor or any other appropriate device controlled by manipulation of the input device.

Figure 15

An alternative embodiment similar to the embodiment shown in *Figure 10* is identified in *Figure 15*. In this embodiment, a deformable resilient element **1501** is implemented by insulating foam. Four strips of electroconductive material **1502**, **1503**, **1504** and **1505** are implemented by electroconductive foam. As shown, the conductive foam is embedded within the deformable resilient element. The conductive foam is substantially similar to the insulating foam but includes particles or fibres of conducting material. Consequently, when stretched, the conducting components are placed in a condition of greater separation thereby increasing overall resistance. Similarly, compression brings more of the conductive components together and therefore increases conduction. Alternative electroconductive materials include other insulating materials such as silicon or rubber filled with conducting particles or fibres. The electroconductive material may itself display resilience, for example in the instance where an electroconductive

material is provided by an elastomeric insulating material incorporating conducting particles or fibres.

As shown in *Figure 15*, a conductive band **1506** electrically connects the conductive foam sections **1502** to **1505** at a top end with the bottom end of the conductive foam sections being connected by electrical terminals to an interface circuit substantially as illustrated in *Figure 14*.

Figure 16

An alternative embodiment of deformable input device is shown in *Figure 16*, capable of detecting movement in all six degrees of freedom; namely translation in the X, Y and Z directions along with rotation about the X, Y and Z axes. A deformable resilient element **1601** is substantially frusta-conical, with its larger substantially circular base **1602** being firmly attached to a substrate such that it is firmly held into position on a table top or similar structure. An upper surface **1603** of the resilient element **1601** has an extension portion **1604** extending therefrom to facilitate manual manipulation.

Six electroconductive material portions are applied over the deformable resilient element **1601** in a substantially diagonal configuration running from a first lower electrical connector to an upper joint and then returning to a further lower connector. The combination therefore has a total of six lower connectors **1611**, **1612**, **1613**, **1614**, **1615** and **1616**. The upper joints are displaced centrally between the lower connectors at upper joint locations **1621**, **1622** and **1623**. A first variably conductive material section **1631** is positioned between lower connector **1612** and upper joint **1621**. A second variably conductive material section **1632** is applied between upper joint **1621** and lower connector **1613**. Similarly, a third variably conductive

material section **1633** is positioned between lower connector **1614** and upper joint **1622**, and a fourth variably conductive material section **1634** is positioned between upper joint **1622** and lower connector **1615**. A fifth variably conductive material section **1635** is positioned between lower connector **1616** and upper joint **1623**, and finally, a sixth variably conductive material section **1636** is positioned between upper joint **1623** and lower connector **1611**. Upper joints **1621** to **1623** are electrically connected by a conductive band **1641**. In this example, conductive band **1641** comprises metallised woven fabric and is connected using pressure sensitive conductive adhesive. Thus, it is possible to supply current through sections **1631** and **1632** by the application of a voltage across connectors **1612** and **1613**. Similarly, it is possible to apply a current through sections **1633** and **1634** by the application of a voltage across connectors **1614** and **1615**. Finally, a current may also flow through sections **1635** and **1636** by the application of a voltage across connectors **1616** and **1611**.

Figure 17

An electrical model for the configuration of *Figure 16* is shown in *Figure 17*. In the model shown in *Figure 17*, six variable resistors are commonly connected at **1641** and each present a terminal **1611** to **1616**.

Figure 18

The input device of *Figure 16* is connected to an interface device substantially similar to that shown in *Figure 13*, but with additional input/outputs and current measuring means. The current measuring means may comprise a fixed resistor connected to, for example, each of connectors

1611, **1613** and **1615**, that can be switched to and from ground. Procedures performed by the interface device are multiplexed, as illustrated in *Figure 18*. Thus, an energising cycle consists of nine stages **1701** to **1709**. Stages **1701** to **1706** involve voltage measurement, whereafter sufficient information has been received in order to define a three-dimensional movement of the deformable element within six degrees of freedom. The information can be processed in accordance with known systems, such as Stewart bridge analysis. Stages **1707** to **1709** involve current measurement, whereafter sufficient information has been received in order to identify compression or indentation of the deformable element.

At step **1701** a voltage is applied to connector **1612**. Connector **1613** is grounded and an output voltage is measured at connector **1614**. It is possible, however, to apply a voltage across connectors **1612** and **1613** and to connect an input buffer with high input impedance to connector **1614** or any other connector that is otherwise unused during this measurement, and to measure voltage at conducting band **1641**. At step **1702** an input voltage is applied to connector **1613**, connector **1614** is grounded and an output voltage is measured at connector **1615**. At step **1703** an input voltage is applied to connector **1614**, connector **1615** is grounded and an output voltage is measured at connector **1616**. At step **1704** an input voltage is applied at connector **1615**, connector **1616** is grounded and an output voltage is measured at connector **1611**. At step **1705** an input voltage is applied to connector **1616**, connector **1611** is grounded and an output voltage is measured at connector **1612**. Voltage measurement is completed, at step **1706**, by an input voltage being applied to connector **1611**, connector **1612** being grounded and an output voltage being measured at connector

1613.

Steps **1707** *to* **1709** involve current measurement. At step **1707** a voltage is applied to connector **1612** and a current is measured at connector **1613**. At step **1708** a voltage is applied to connector **1614** and the current is measured at connector **1615**. Finally, at step **1709** a voltage is applied to connector **1616** and a current is measured at connector **1611**.

The resistance of the six variably conductive material sections **1631** to **1636** either increase or decrease, according to the construction of the material, in response to the deformable element deforming under an applied squeezing action. The current measurements performed at steps **1707** to **1709** provide an indication as to the current flowing through the deformable element, which may be related to an extent of pressure applied to the deformable element. Thus, steps **1707** *to* **1709** provide for a squeezing, compressing or denting action applied to the deformable element to be detected, and hence compression or indentation of the deformable element to be detected.

The multiplexed procedure sequence detailed in *Figure 8* can be executed according to one of two modes, namely monitoring mode and active mode. In monitoring mode, steps **1701** to **1706** are performed at a first scan rate to minimise power consumption, and when motion is detected, steps **1701** to **1709** are performed at a second faster scan rate in active mode, during which full sets of measurements are obtained.

Figure 19

An application for a device of the type shown in *Figure 16* is shown in *Figure 19*. A portable deformable input device **1901** is attached to a base

plate **1902**, configured to be supported by a solid object. A clamp **1903** has been attached to the top of the deformable input device **1901** configured to receive a manually-operable games controller **1904**. Thus, with the games controller **1904** being supported within the clamp **1903** it is possible for a game player to provide additional information to an appropriately programmed game. Thus, for example, a configuration of this type would be particularly suitable for 3D action games and flight simulators etc. In addition to receiving an input from the controller **1904** a computer system also receives an input from an interface device associated with the deformable input device **1901** possibly over a serial or a USB computer interface.

Figure 20

The configuration shown in *Figure 19* may be used in a situation as shown in *Figure 20*. Thus, base plate **1902** is supported by a chair and the deformable input device is thus held down by a user's legs. The control device **1904** is then held in an orientation substantially similar to that of a steering wheel or similar input device thereby providing the user with a realistic and enhanced operation stance thereby significantly enhancing the interaction with the game or program itself; all achieved by use of a relatively inexpensive, durable additional control apparatus.

Figure 21

An alternative application for a deformable input device is illustrated in *Figure 21*. Soft toy **2101** takes the form of a teddy bear, and utilises, in this example, a plurality of deformable input devices, indicated at **2102**, **2103**, **2104**, **2105**, **2106** and **2107**, each comprising three electrical

terminals. The input devices **2101**, **2102**, **2103**, **2104**, **2105**, **2106** are all electrically connected, in this example by means of a conductive ring **2108**. The terminals of the input devices are distributed about the soft toy **2101**. In the shown arrangement, an input device is located in each region corresponding to an ear of the toy **2101**, an arm of the toy **2101** and a leg of the toy **2101**. During play with the toy **2101**, manipulation of the main body or extremities of the toy **2101** can be detected, and for example used to raise a visual, aural or tactual effect response.

Figure 22

An alternative shape format for a deformable input device is illustrated in Figure 22, in the form of a hemisphere. Input device **2201** utilises two strips of electroconductive material **2202** and **2203**, operatively coupled with the domed surface of the hemisphere. As shown, each of the conductive tracks **2202**, **2203** extend over the domed surface between opposite ends of a diameter of the substantially planar base of the hemispherical input device **2201**. The strips **2202**, **2203** are arranged substantially perpendicular, with a region of electrical contact, indicated by shaded region **2204,** between the two strips **2202**, **2203**, in the region of the apex of the domed surface. This arrangement and is similar to that of the deformable input device described with reference to, and as illustrated in, *Figure 10*, and may utilise a similar scanning sequence during operation.

Figure 23

A further alternative shape format for a deformable input device is illustrated in *Figure* 23, in the form of a sphere. Input device **2301** utilises

three strips of electroconductive material **2302, 2303** and **2304**, operatively coupled with the resilient material forming the main body of the sphere. As illustrated, each of the conductive strips **2302, 2303** and **2304** extend around the circumference of a great circle of the spherical input device **2301**, and are arranged such that one is substantially perpendicular to another. The strips **2302, 2303** and **2304** intersect to form six regions of electrical contact around the spherical body, for example in the region indicated by shaded region **2305** through which strips **2302** and **2303** pass.

Figure 24

An alternative embodiment of deformable input device is illustrated in *Figure 24*. Input device **2401** takes on a more two-dimensional form. The input device **2401**, comprises four strips of elastomeric electroconductive material **2402**, **2403**, **2404** and **2405**, each strip having one end connected to a conductive ring **2406** and the other end connected to a frame **2407**. In this example, each of the strips **2402**, **2403**, **2404**, **2405** is attached to a different side of a substantially square frame, as though to divide the square into four smaller squares. This arrangement is similar to that of the deformable input device described with reference to, and as illustrated in, *Figure 10*, but in a two-dimensional format. In the relaxed state of this arrangement, the conductive ring **2406** is substantially central within the frame area.

Preferably, frame **2407** is formed from a board of rigid material so as to provide a backing for the conductive strips **2402**, **2403**, **2404**, **2405**. In use, the conductive strips **2402**, **2403**, **2404**, **2405** are moved around over the backing frame **2407**. Therefore it is preferable to have low friction between the backing frame **2407** and the strips **2402**, **2403**, **2404**, **2405** so that the

strips may slide easily under manually applied pressure and to reduce wear. However, a picture frame style arrangement may be utilised.

Input device **2401** may optionally have a stretch cover, indicated generally by dotted line **2408**. The stretch cover may underlie or overlie the strips **2402**, **2403**, **2404**, **2405**, and may be secured to both the frame **2407** and the strips **2402, 2403, 2404, 2405** or one of these only.

The present embodiment utilises a conductive ring **2406**, which when moved from the at rest position causes deformation of the strips **2402**, **2403**, **2404**, **2405** from the at rest condition. In the example shown, the conductive ring **2406** takes the form of an O-ring into which a finger may be inserted to assist movement of the conductive ring **2406** around within the area of the frame **2407**. Thus the conductive ring **2406** also functions to enable a user to achieve a more secure grip on the manipulation surface of the input device **2401**.

An alternatively type of gripping member, for example in the form of a bump or shaped handle raised from the surface of the input device **2401**, may be provided. Such a gripping member would provide a similar function to that of extension portion **1604** of input device **1601** and clamp **1903** of input device **1901**, in assisting translation of movement effected by a user to a detectable manipulation of the deformable input device. This feature may be advantageous for users with restricted dexterity.

Figure 25

Figure 25 shows deformable input device **2401** following movement of the conductive ring **2406** from the at rest position. It can be seen from this Figure that conductive strips **2402** and **2405** are now shorter than in the at

rest position and conductive strips **2403** and **2404** are now longer than in the at rest position. Thus, moving the conductive ring **2406** from the at rest position causes each of the strips **2402**, **2403**, **2404**, **2405** to experience internal changes in tension and length. In this way, the input device **2401** is responsive to shear forces. By establishing a voltage gradient across opposed pairs of conductive strips, in this example across strips **2402** and **2404** or strips **2403** and **2404**, and taking a voltage reading from one of the other pair of strips, an extent of manually applied pressure and a direction of manipulating movement relative to the at rest condition can be determined.

Figure 26

An alternative embodiment of deformable input device is illustrated in *Figure 26*. Input device **2601** takes a similar form to input device **2401**, having a similar two-dimensional format and a frame **2602**. However, input device **2601** differs in that it utilises a layer of elastic electroconductive fabric **2603** to which four point electrical terminals **2603, 2604, 2605** and **2606** are connected. The four electrical terminals **2603, 2604, 2605**, **2606** allow deformation to be detected in two axes, as described above with reference to *Figure 10*. This type of arrangement is configured to detect manipulation of any area of the electroconductive material **2603**. Dotted line circle **2608** indicates a notional starting position. In addition, the deformable resilient element of the input device **2601** and the electroconductive material of the input device **2601** are both provided by the layer of elastic electroconductive fabric **2603**. Thus, these two elements of the deformable input device may be operatively coupled by virtue of the elements being combined in a single layer. Optionally, however, an additional stretch cover,

indicated generally by dotted line **2609,** may be provided.

In the shown arrangement, the frame **2602** takes the form of a substantially square backing board, with one point contact **2603, 2604, 2605, 2606** positioned substantially half way along each side. With this arrangement, voltage swing is less detectable at the corner regions of the frame area than in the centre of the frame **2602**.

This arrangement is suitable for use in applications in which relative rather than absolute positional information is sufficient. Practical applications include use as a sensor, or as a cursor control or menu navigation tool.

Claims

1. A manually deformable input device responsive to manually applied pressure, comprising

a deformable resilient element configured to deform in response to said manually applied pressure, operatively coupled with

an electroconductive material applied configured to exhibit changes in conductance (resistance) in response to being stretched; and

an electrical interface device configured to supply electrical current through said electroconductive material via a first terminal and a second terminal, wherein:

a third terminal is connected at an intermediate position; and

said interface device is configured to receive a voltage from said third terminal.

2. An input device according to claim 1, wherein said electroconductive material is applied over said deformable resilient element.

3. An input device according to claim 1, wherein said electroconductive material is embedded within said deformable resilient element.

4. An input device according to claim 1, wherein said deformable resilient element is constructed from a foam or foam-like material, rubber or silicone rubber.

5. An input device according to claim 1, wherein said

electroconductive material is a textile fabric.

6. An input device according to claim **5**, wherein said textile fabric is a warp knit, a weft knit or a weave that includes conductive fibres.

7. An input device according to claim **1**, wherein said electroconductive material is an elastomeric material having electroconductive components therein.

8. An input device according to claim **1**, wherein said deformable resilient element and said electroconductive material are provided by an elastomeric electroconductive textile.

9. An input device according to claim **1**, wherein the conductance of said electroconductive material increases when said material is stretched.

10. An input device according to claim **1**, wherein said interface device is configured to measure a divided voltage between said first terminal and said second terminal.

11. An input device according to claim **1**, wherein said interface device is configured to produce an output signal.

12. An input device according to claim **11**, wherein said output signal is used to:

control a motor;

provide an input command to a game;

raise an alarm condition;

raise a visual, aural or tactual effect response;

control a cursor;

navigate a menu.

13. An input device according to claim **1**, configured to be responsive to translation, rotation, compression or indentation of said deformable resilient element.

14. An input device according to claim **1**, comprising a frame.

15. An input device according to claim **1**, comprising a gripping member.

16. An input device according to claim **1**, further comprising a fourth terminal.

17. A method of detecting deformation of a deformable input device, said input device comprising

a deformable resilient element configured to deform in response to applied pressure, operatively coupled with

an electroconductive material configured to exhibit changes in conductance (resistance) in response to being stretched, and

a first electrical terminal, a second electrical terminal and a third electrical terminal, said third terminal at a position intermediate said first terminal and said second terminal; said method comprising the steps of:

establishing a voltage gradient across said electroconductive

material via said first terminal and said second terminal, and

measuring a voltage appearing at said third terminal.

18. A deformable input device substantially as herein described with reference to and as shown in *Figures 1* to *26* of the accompanying drawings.

19. A method of detecting deformation of a deformable input device substantially as herein described with reference to and as shown in *Figures 1* to *26* of the accompanying drawings.

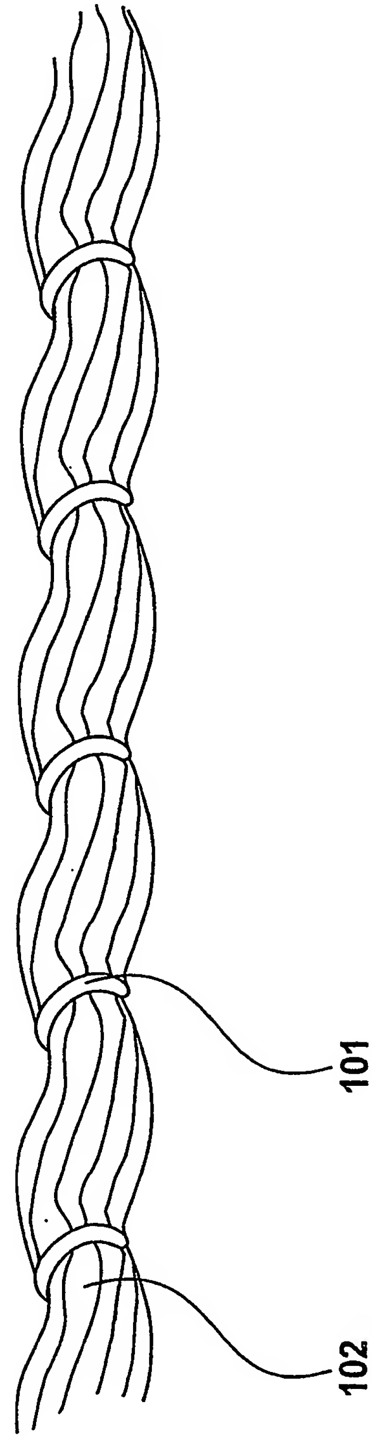


Figure 1

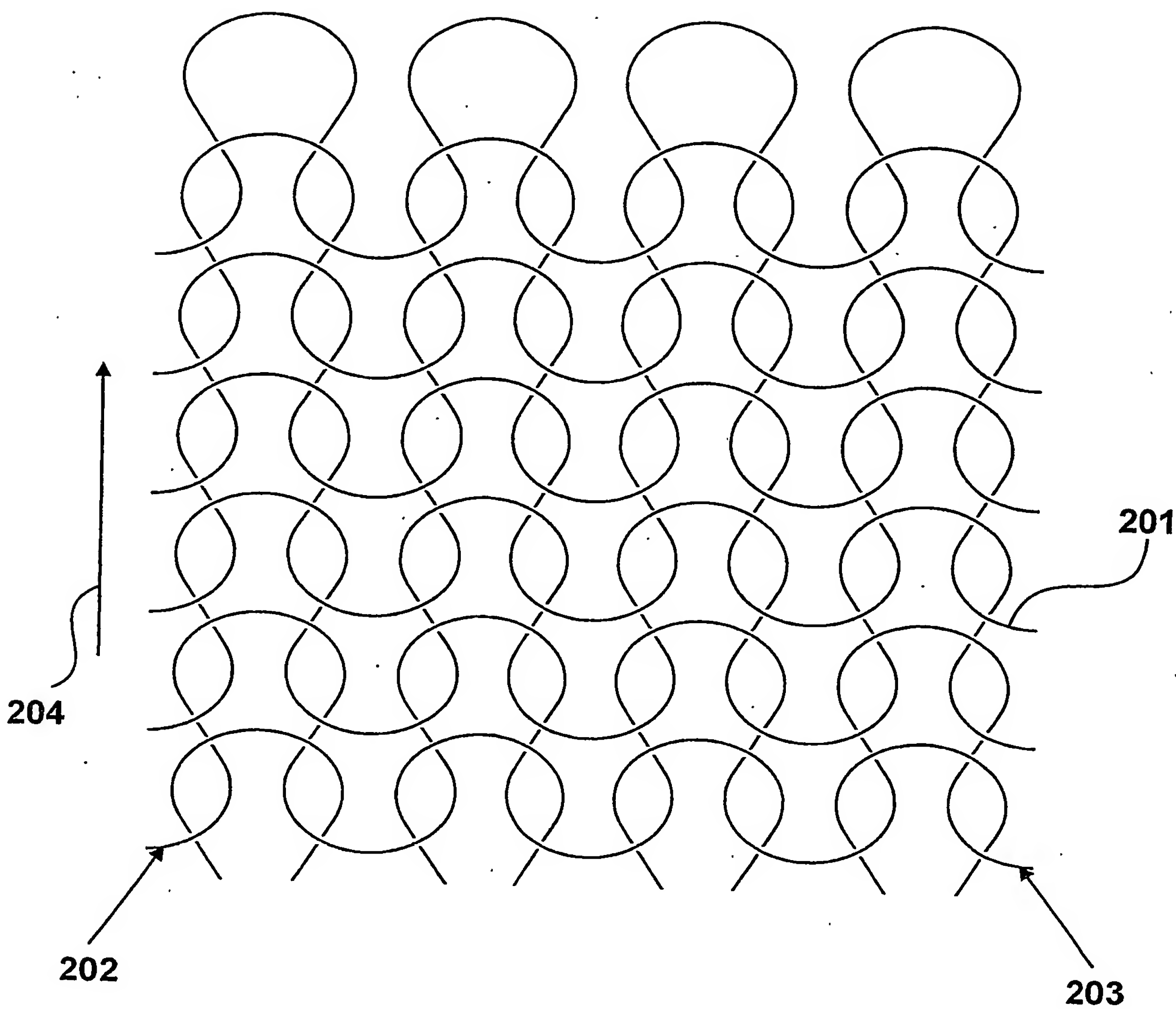


Figure 2

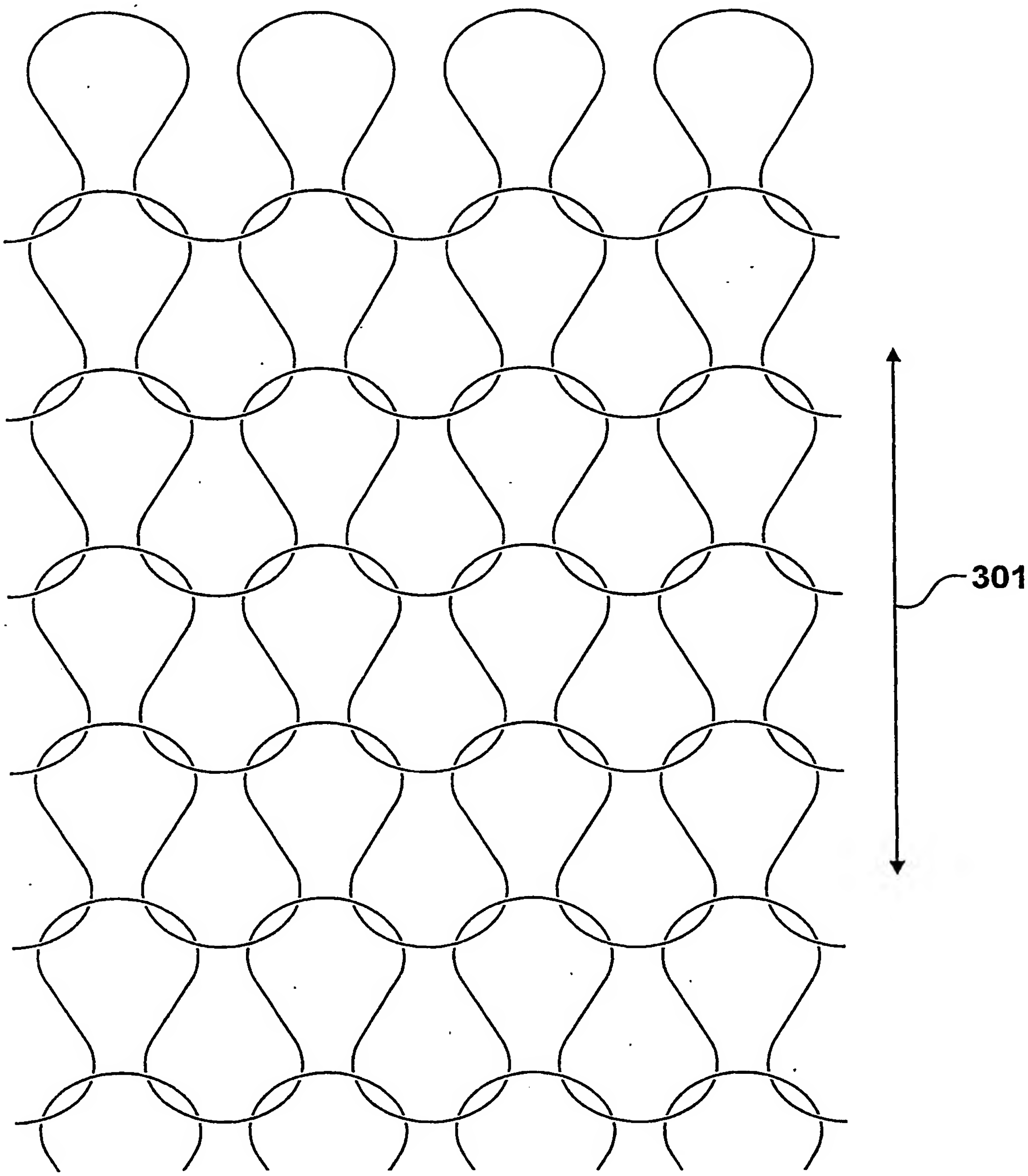


Figure 3

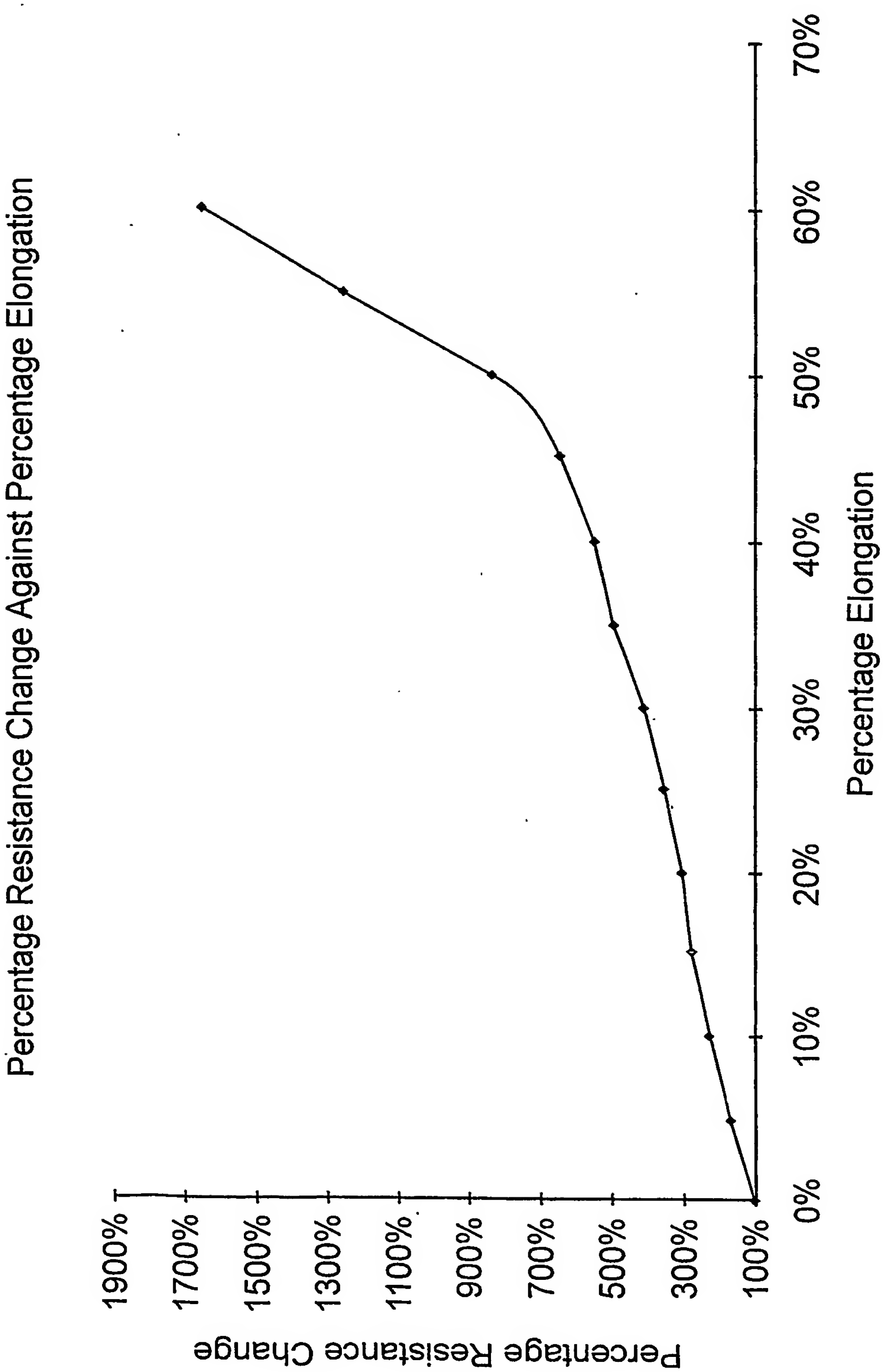
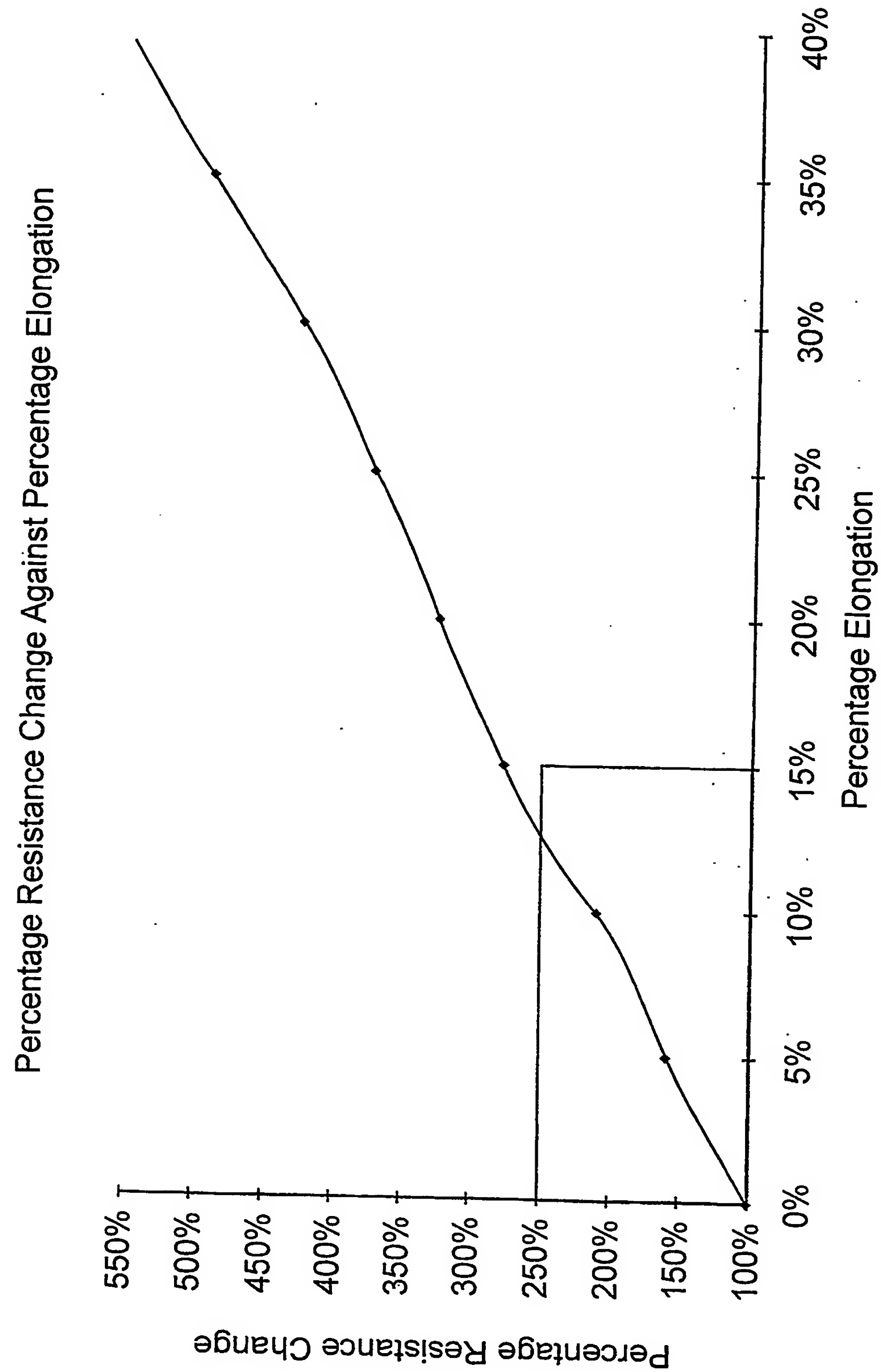

Percentage Resistance Change Against Percentage Elongation
Percentage Resistance Change
1900%
1700%
1500%
1300%
1100%
900%
700%
500%
300%
100%
0%
10%
20%
30%
40%
50%
60%
70%
Percentage Elongation

Figure 4


Percentage Resistance Change Against Percentage Elongation
Percentage Resistance Change
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500%
450%
400%
350%
300%
250%
200%
150%
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0%
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10%
15%
20%
25%
30%
35%
40%
Percentage Elongation

Figure 5

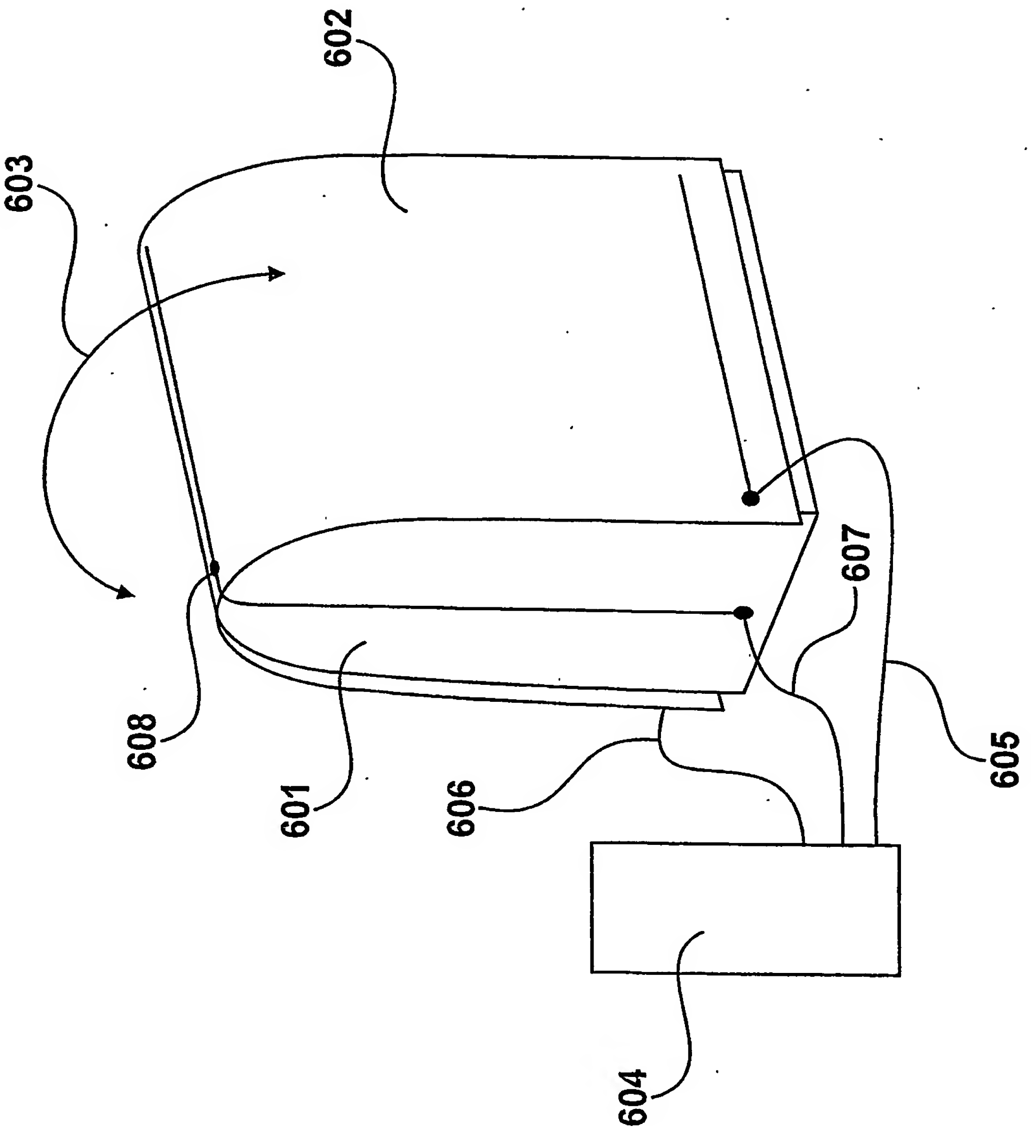


Figure 6

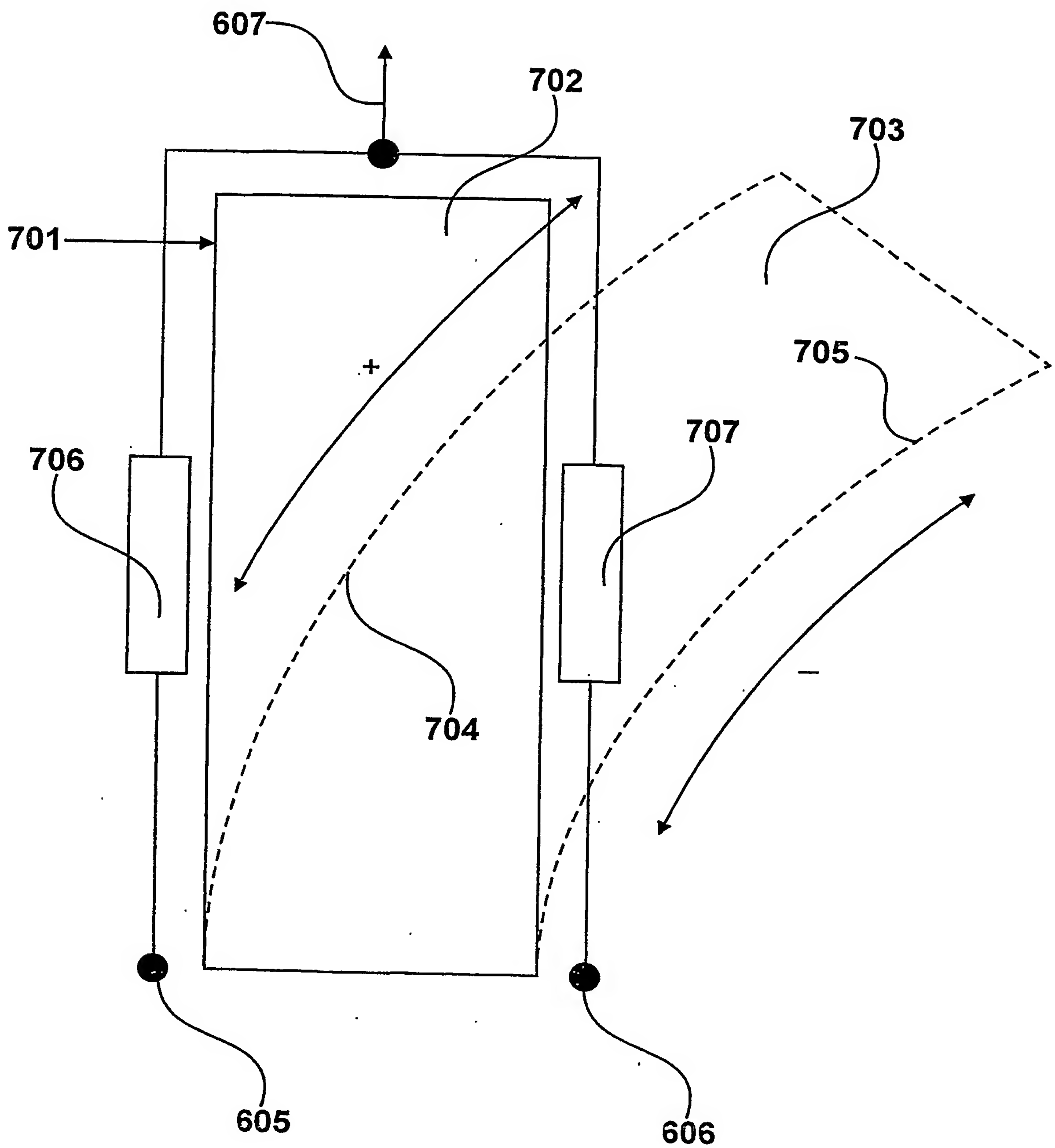


Figure 7

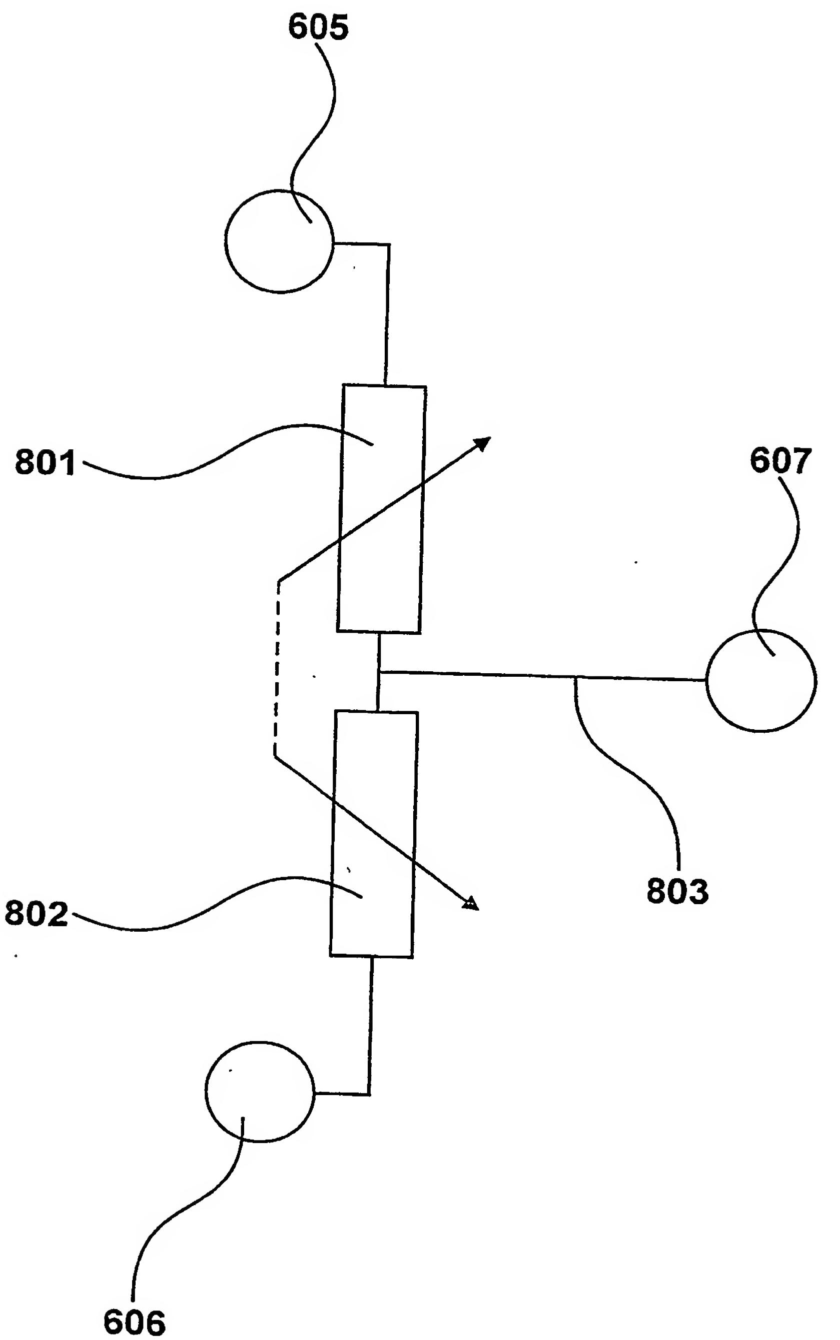


Figure 8

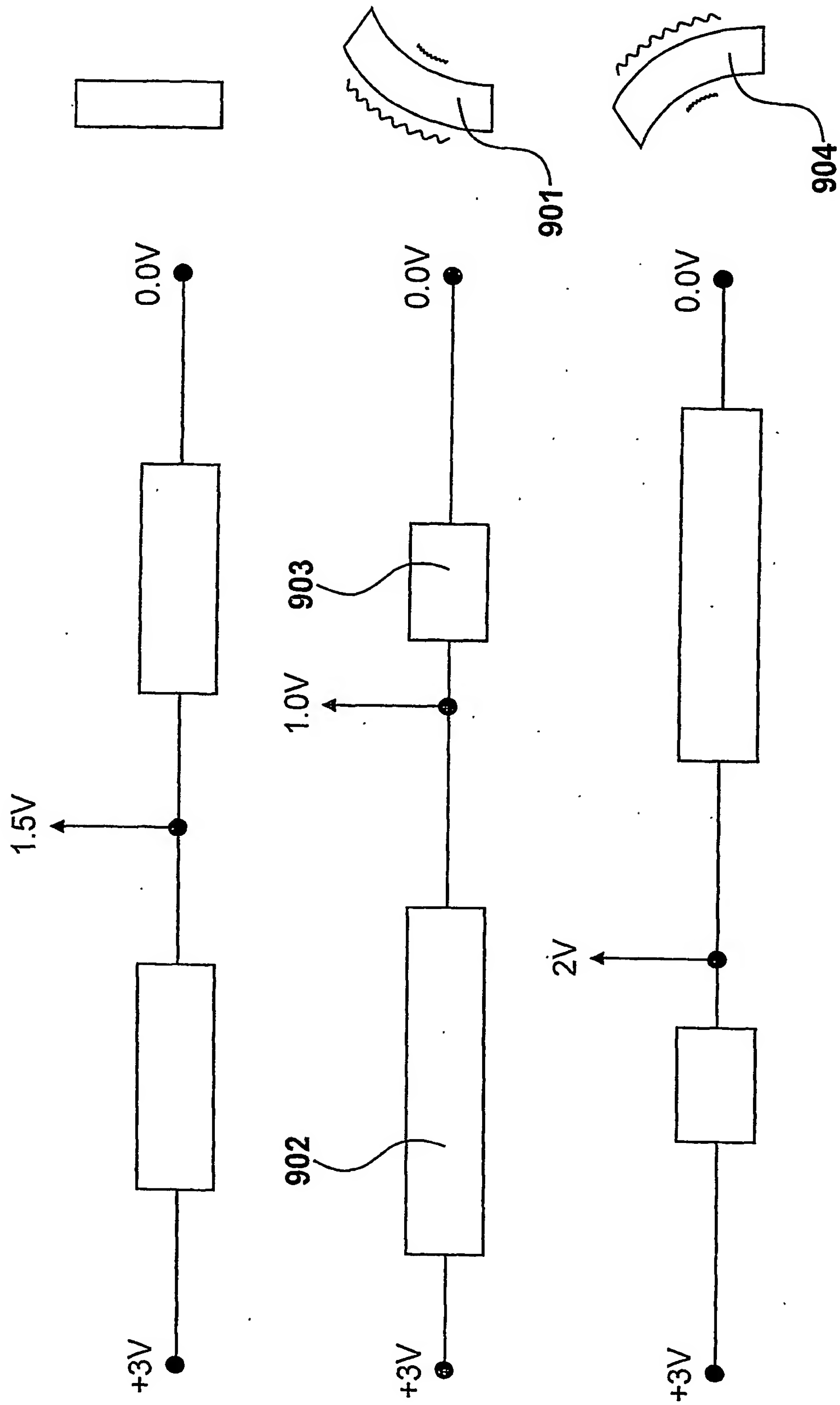


Figure 9

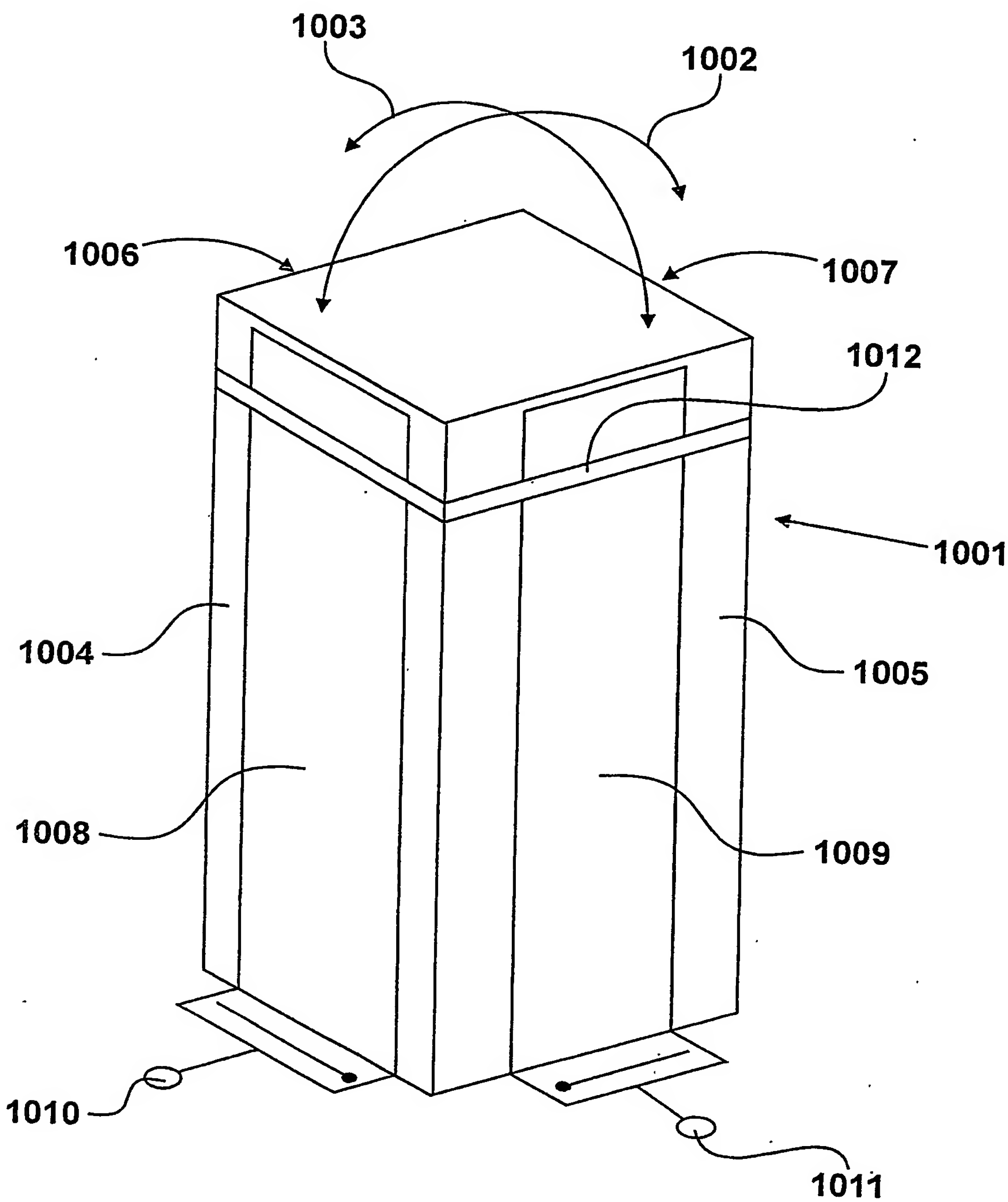


Figure 10

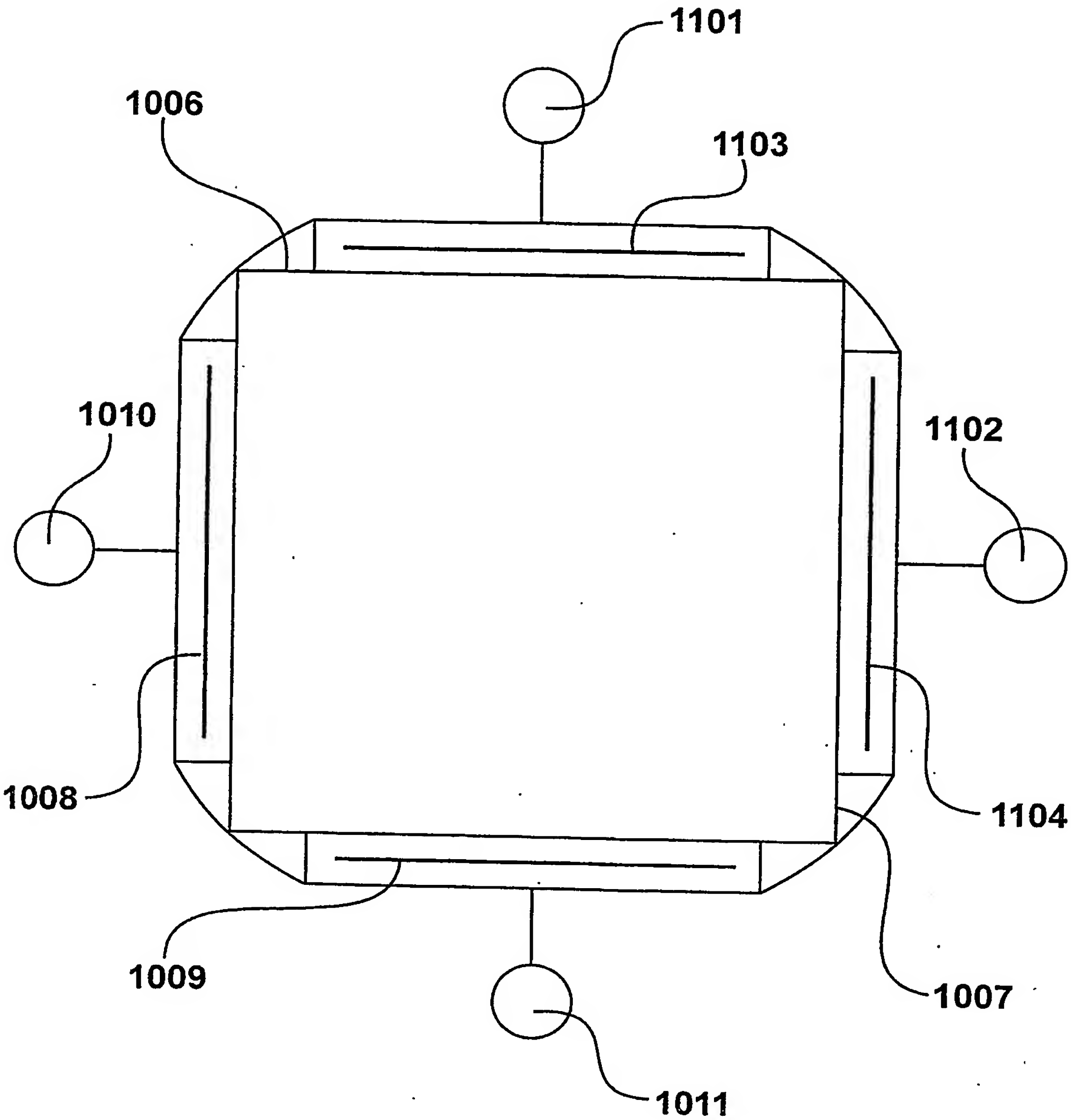


Figure 11

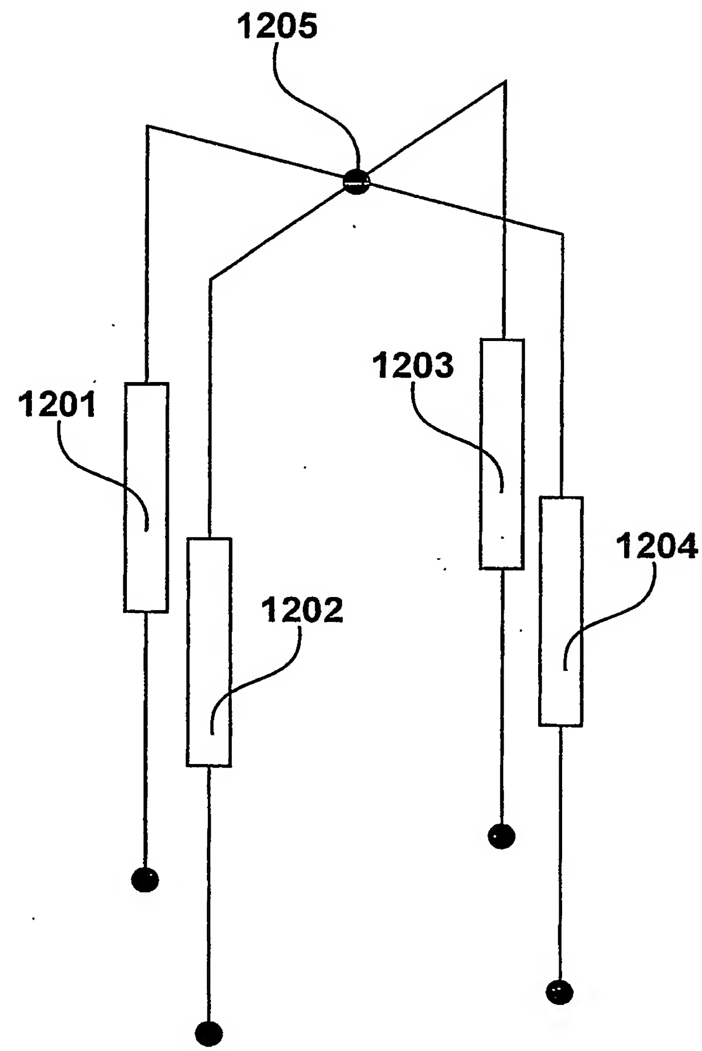


Figure 12

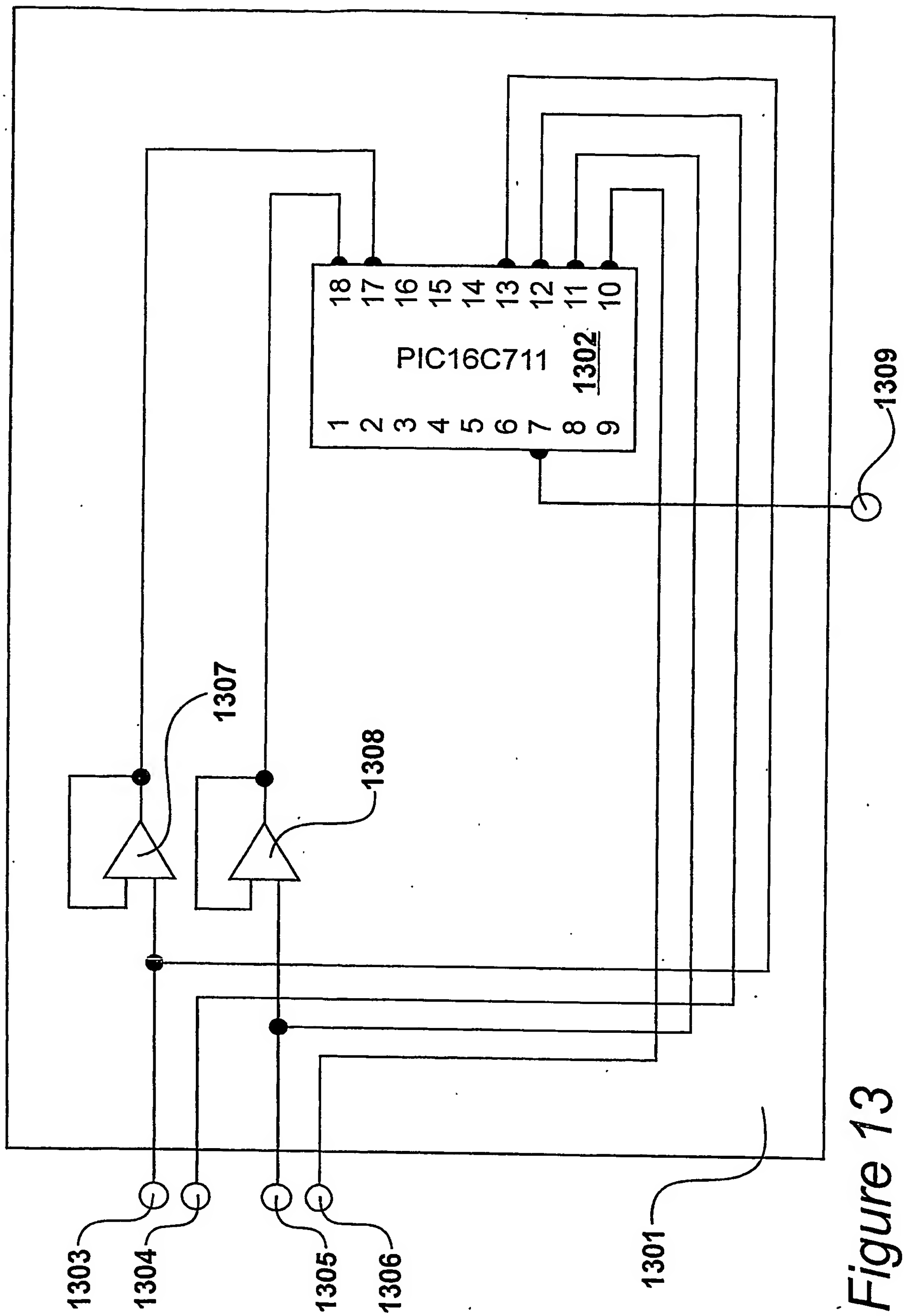

PIC16C711
1302
1 2 3 4 5 6 7 8 9
18 17 16 15 14 13 12 11 10
1301
1303
1304
1305
1306
1307
1308
1309

Figure 13

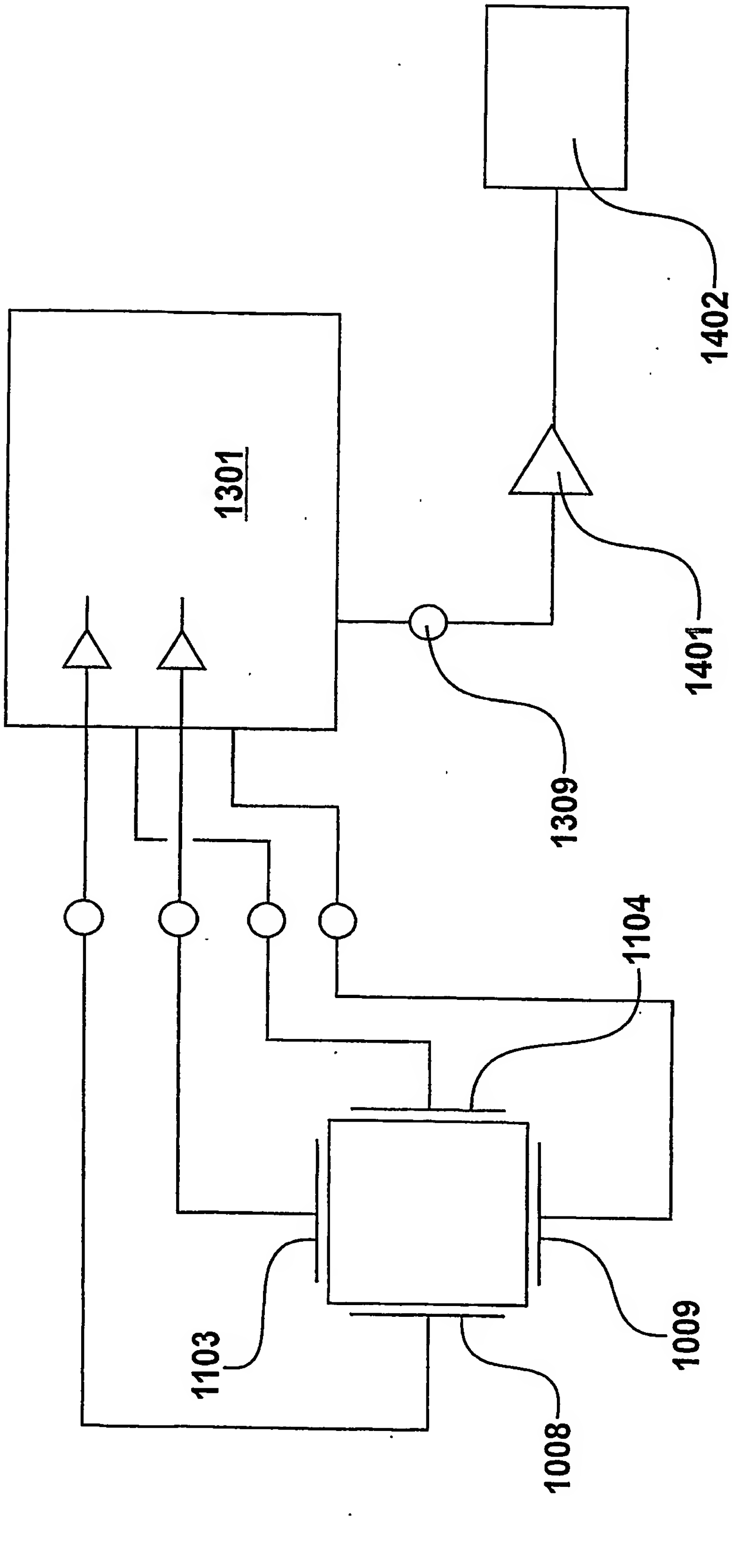


Figure 14

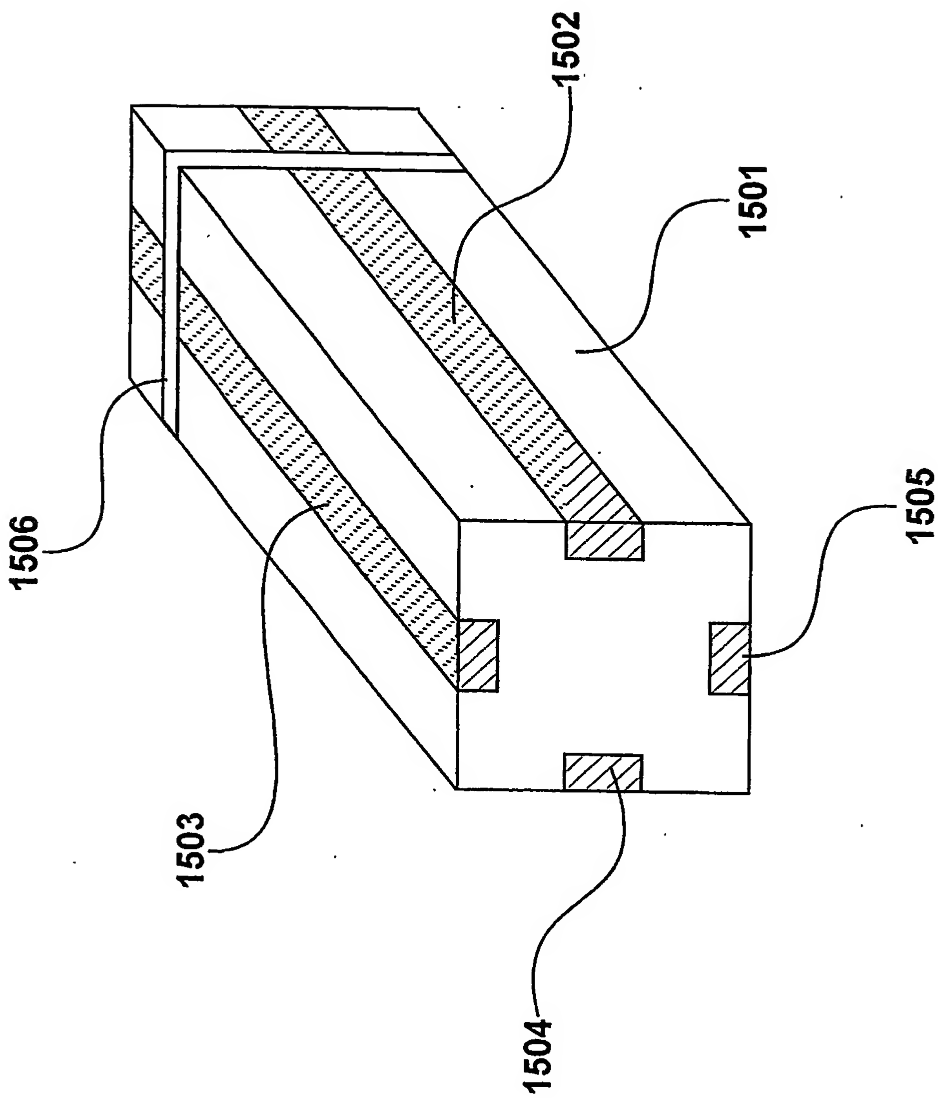
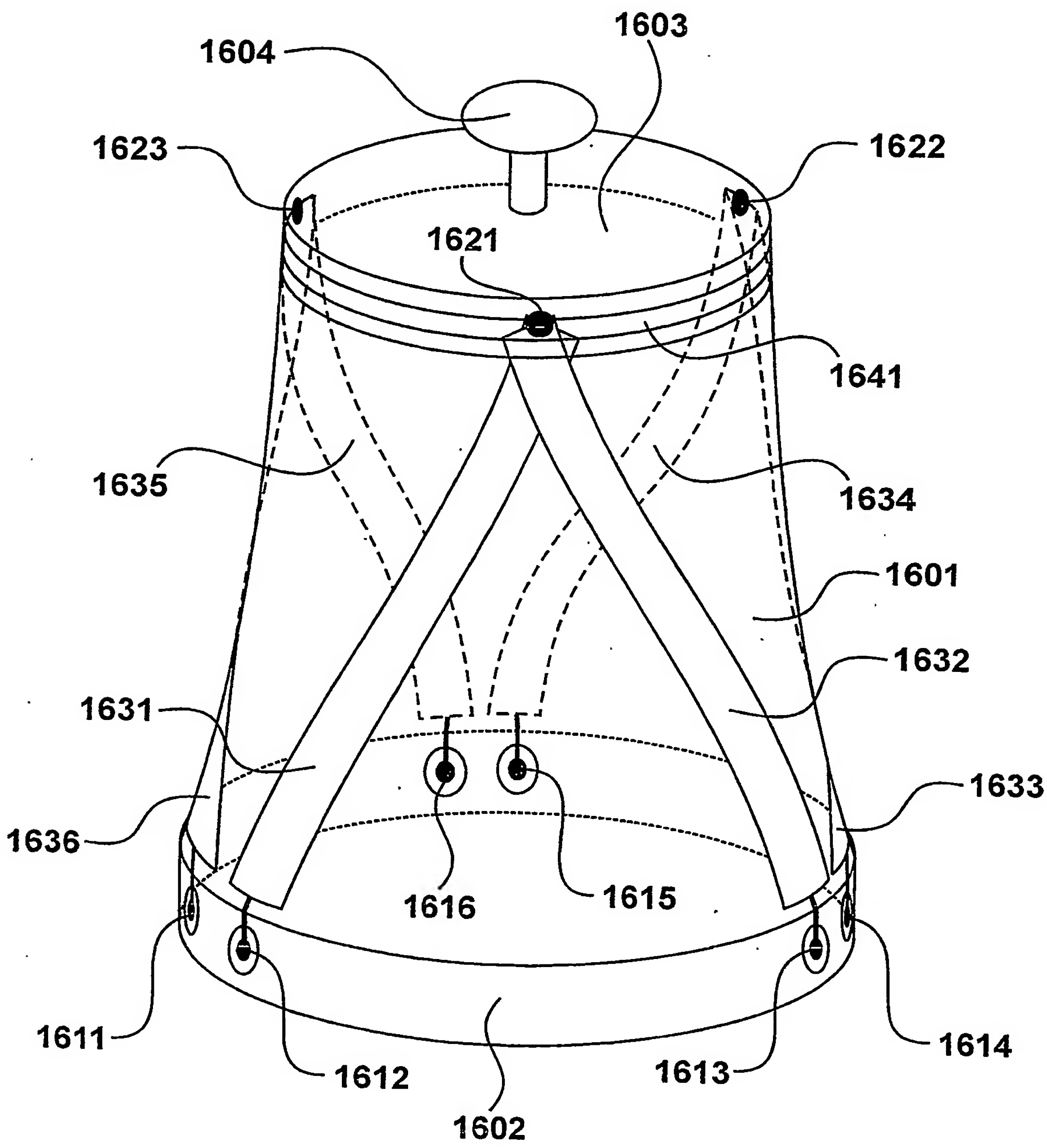


Figure 15


1604
1603
1623
1622
1621
1641
1635
1634
1601
1632
1631
1633
1636
1616
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1611
1612
1613
1614
1602

Figure 16

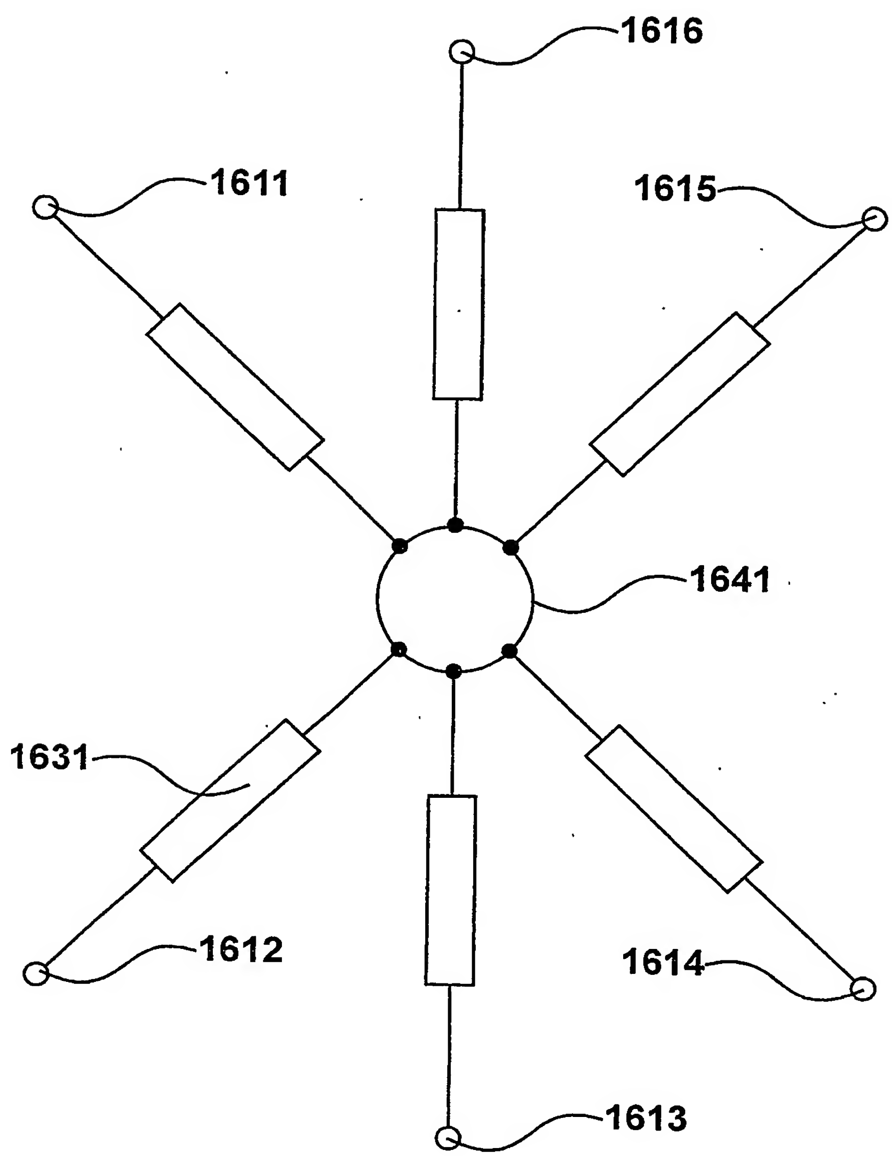

Figure 17

	1612	1613	1614	1615	1616	1611
1701	Vin	0	Vout	-	-	-
1702	-	Vin	0	Vout	-	-
1703	-	-	Vin	0	Vout	-
1704	-	-	-	Vin	0	Vout
1705	Vout	-	-	-	Vin	0
1706	0	Vout	-	-		Vin
1707	+V	I				
1708			+V	I		
1709					+V	I

Figure 18

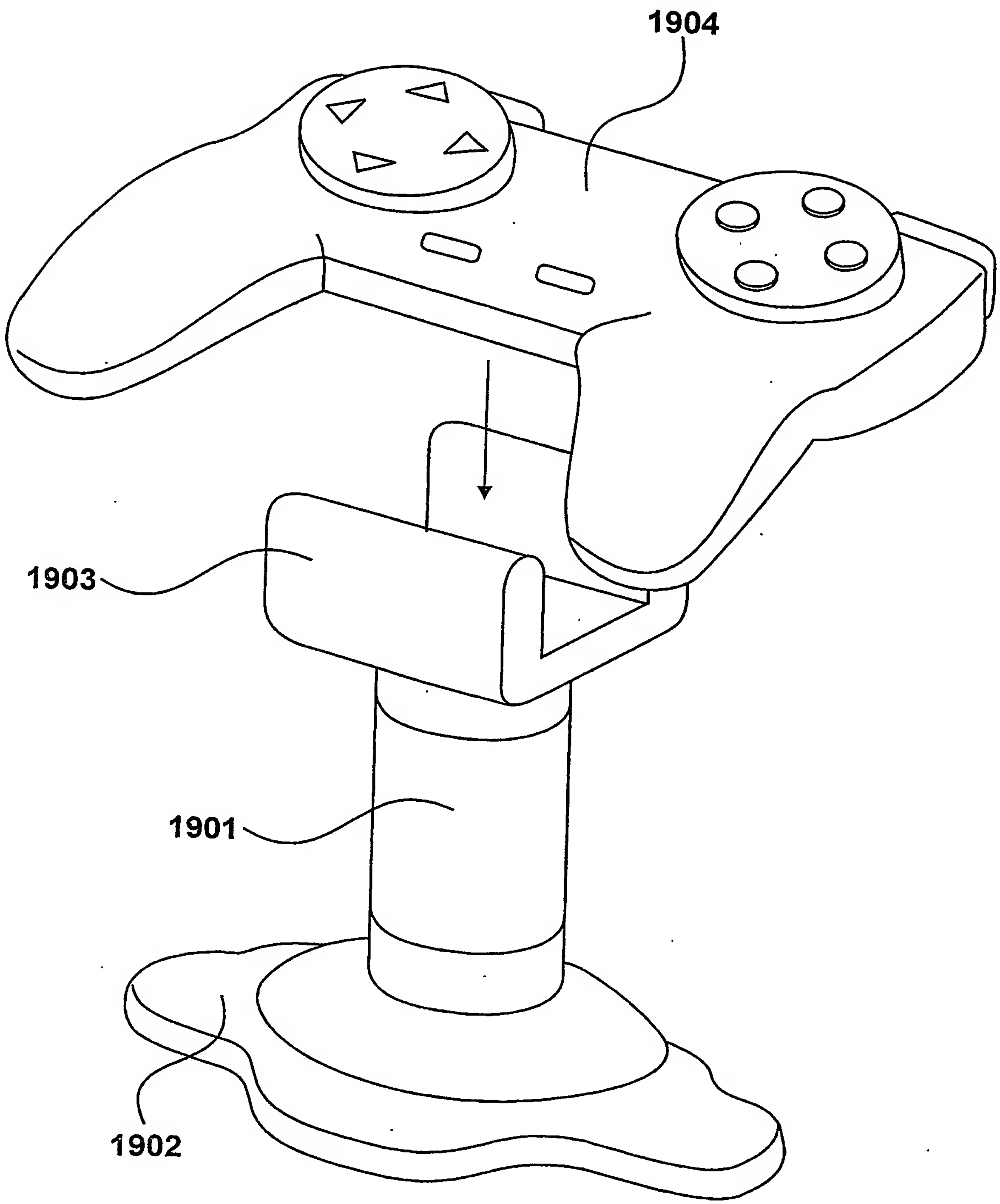

Figure 19

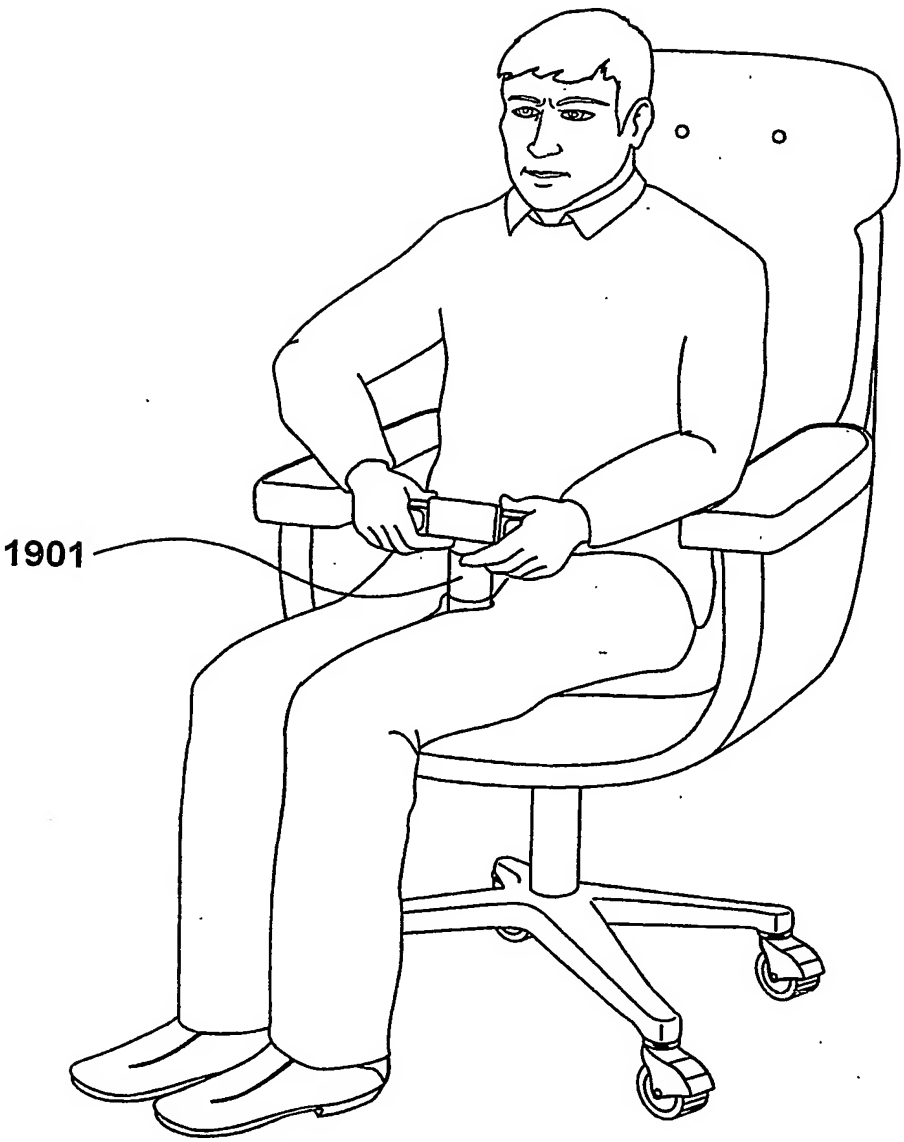

Figure 20

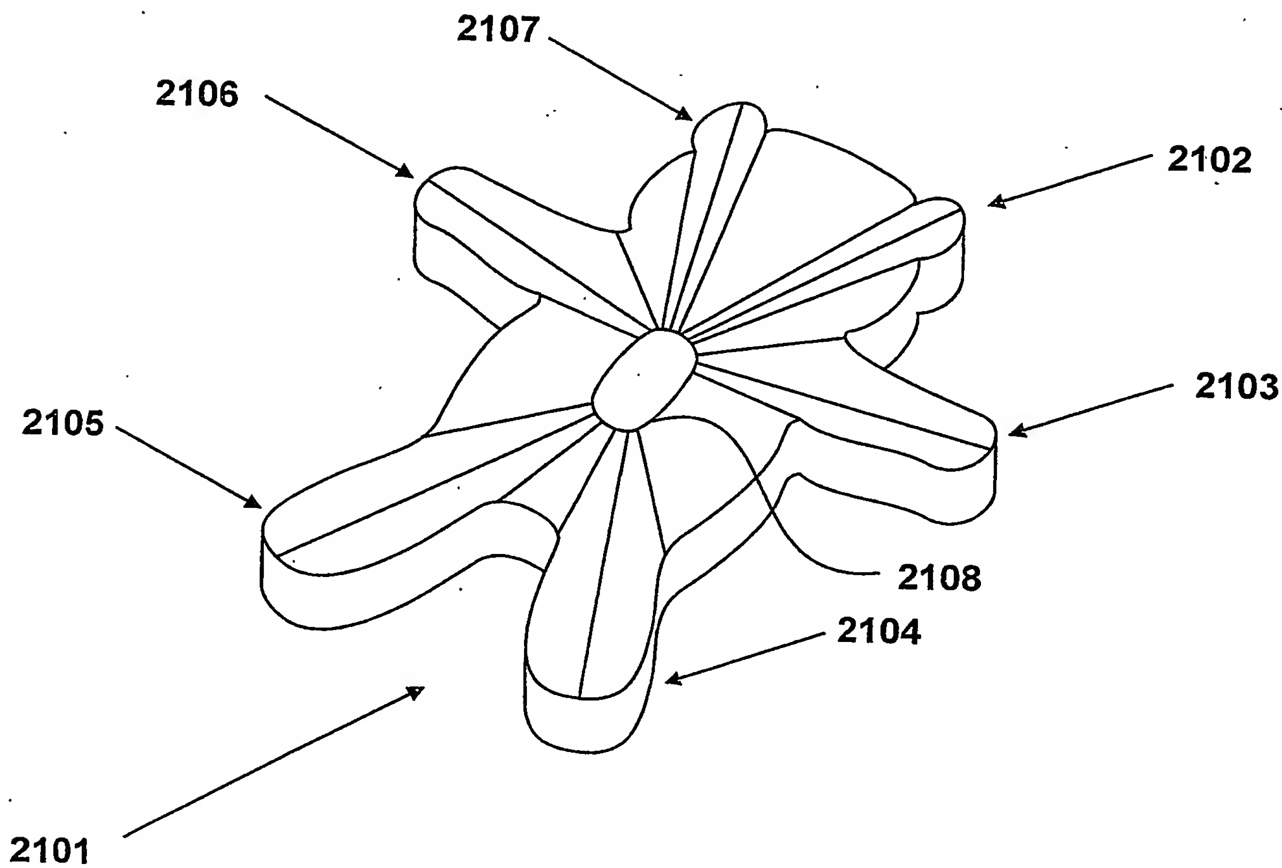

Figure 21

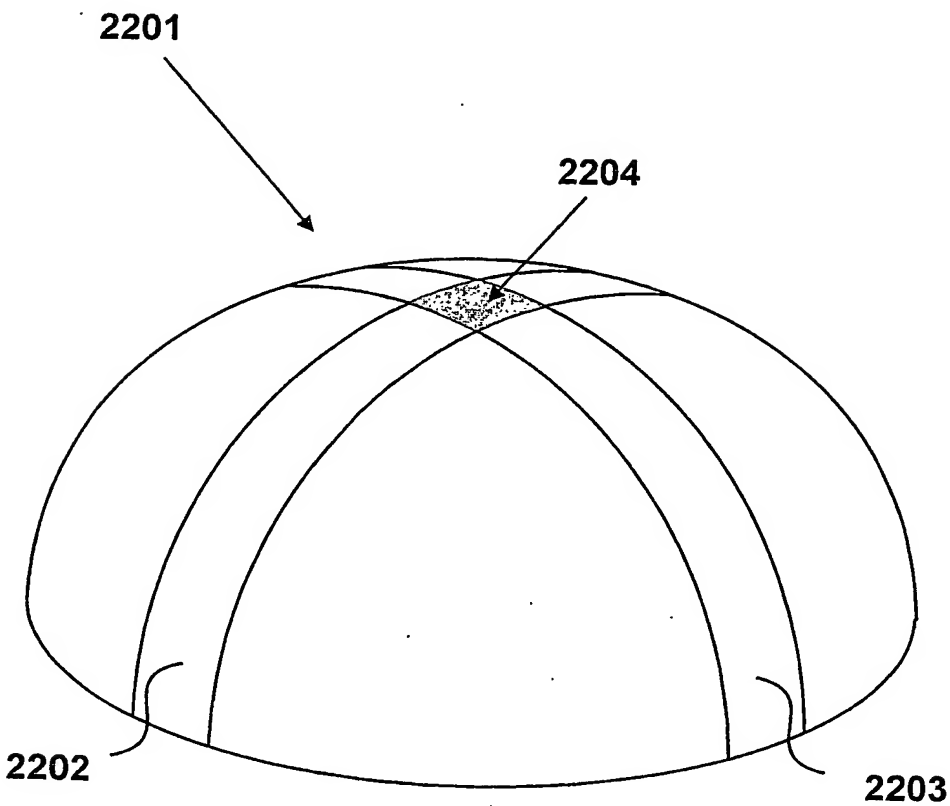

Figure 22

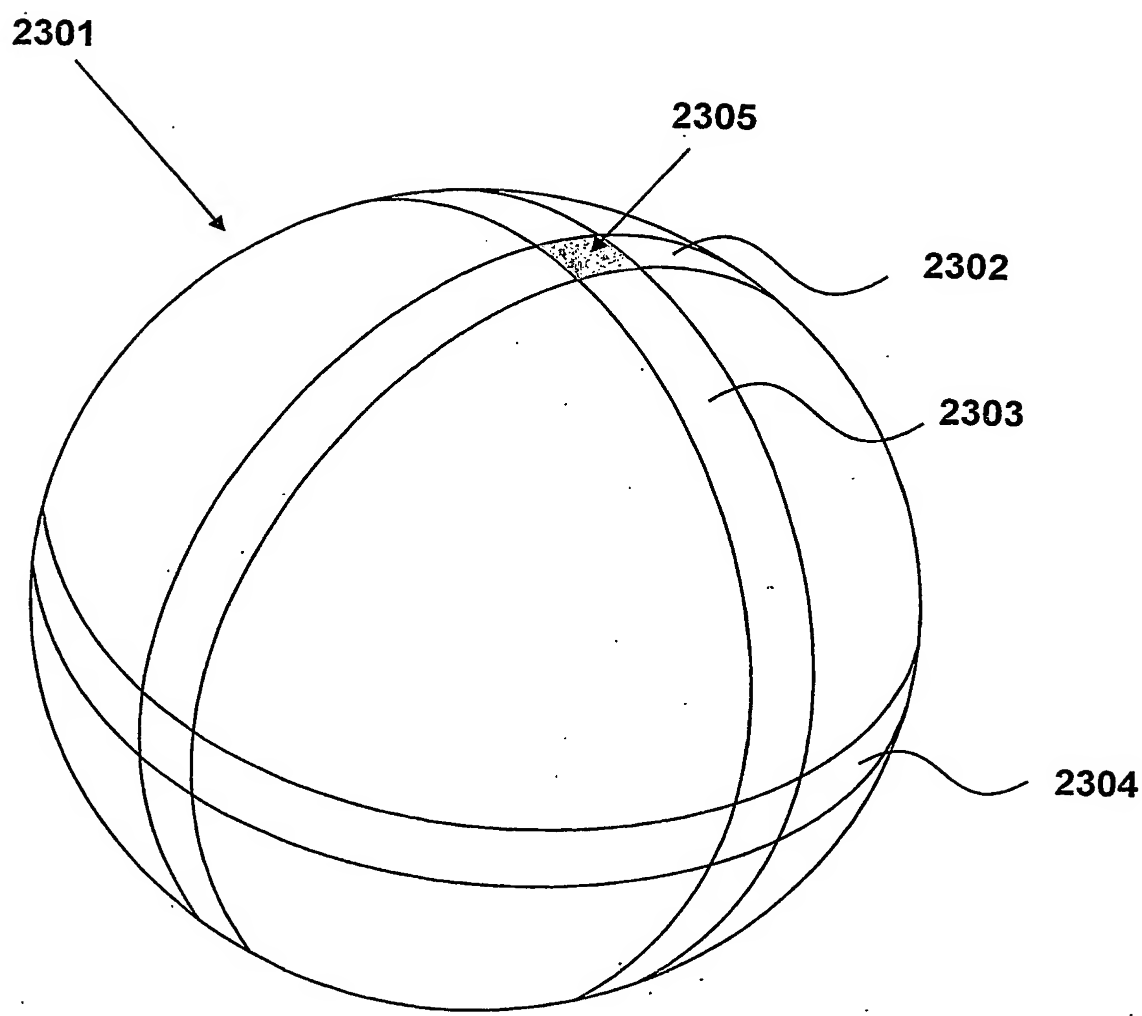

Figure 23

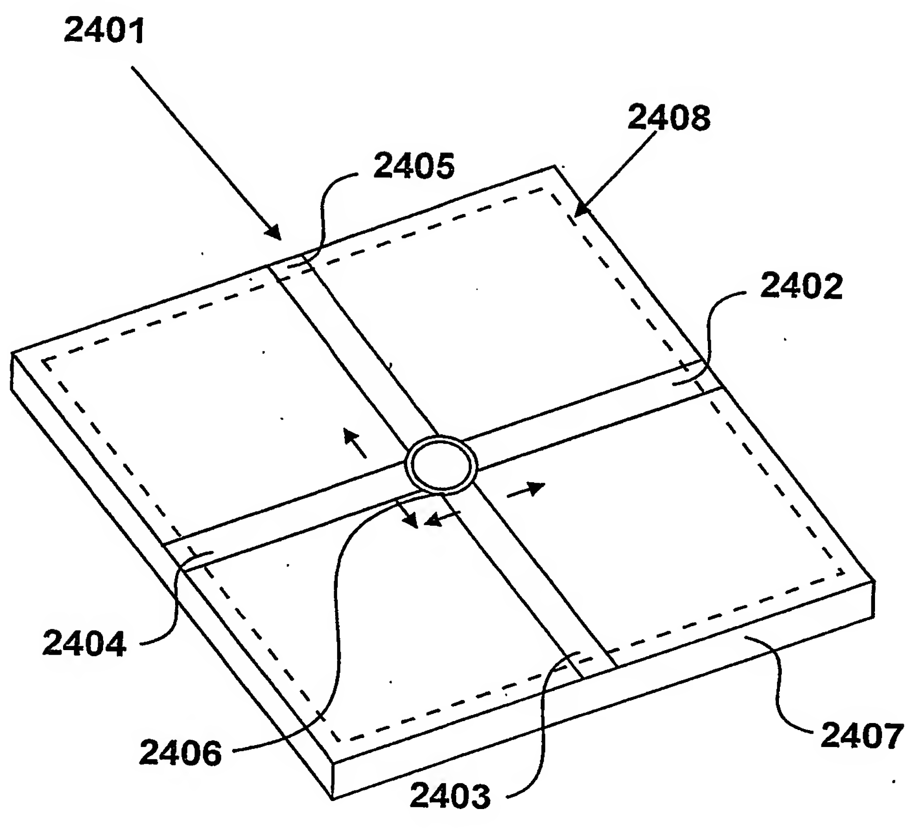

Figure 24

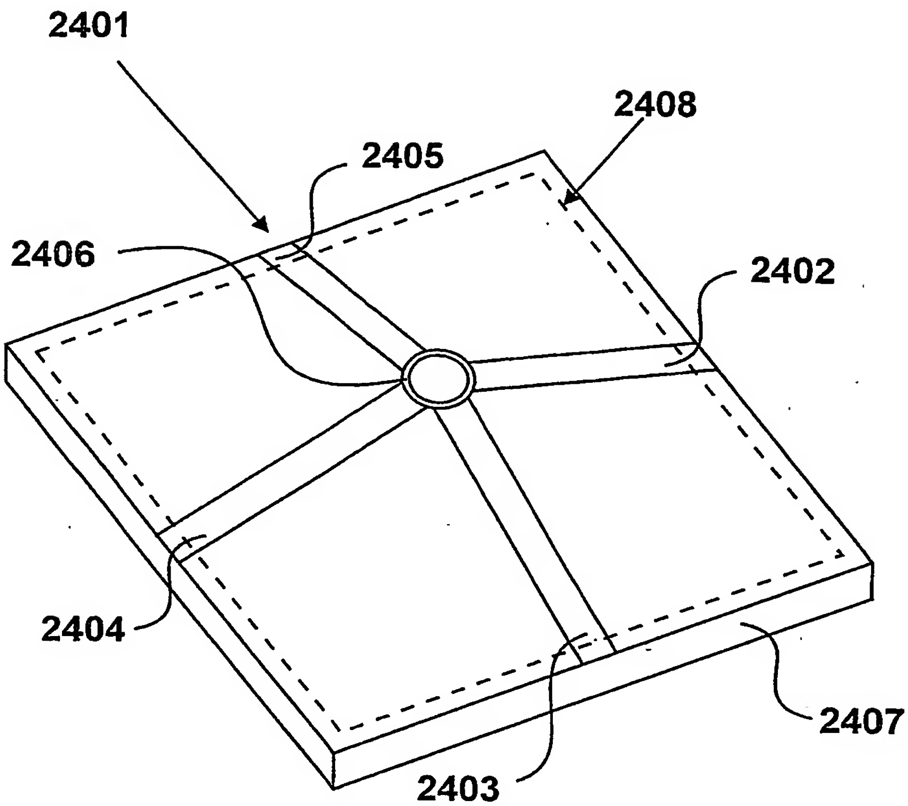

Figure 25

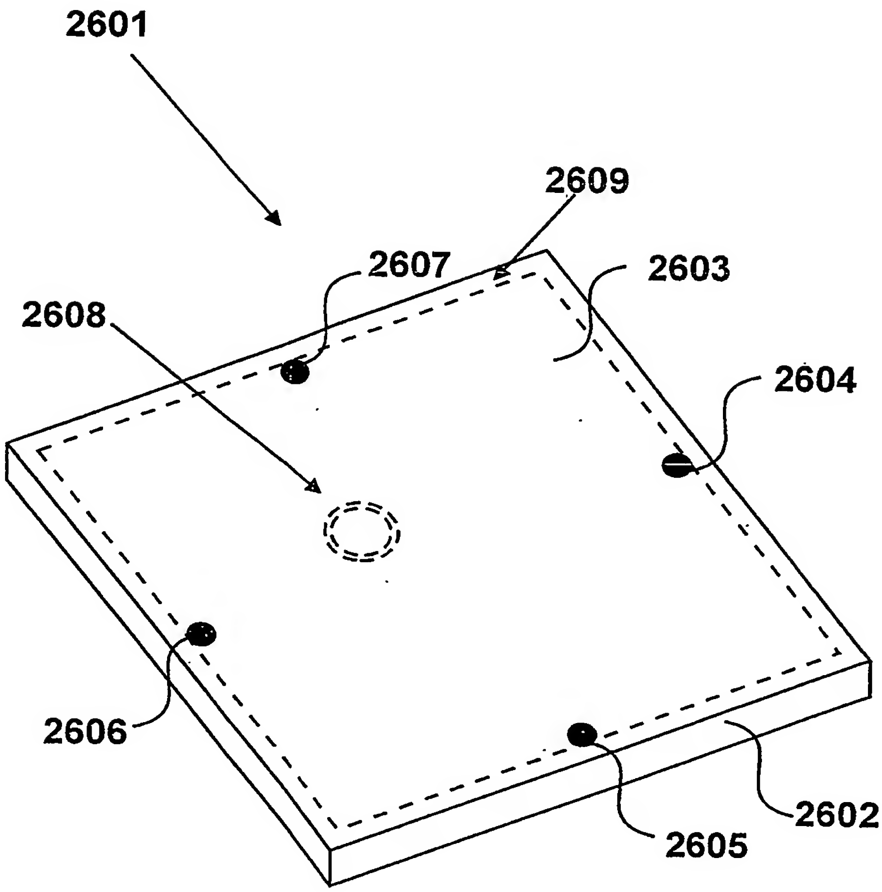

Figure 26